COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

July 1954

A Continuing Policy

Twenty-five years ago this month, the first issue of COMBUSTION was published. The editorial page of that issue was devoted to a statement of policy from which the following paragraphs are quoted. They expressed basic aims and objectives which have served to guide us through the past quarter century and will continue to do so in the future.

• • •

"The accurate interpretation and dissemination of news concerning present-day practice, new developments and future trends in the fields of fuel burning and steam generation are matters of vital importance both to the manufacturers who have contributed to this progress and to the engineers who seek to take advantage of the improvements made in methods and equipment. An authoritative publication, which will devote itself specifically to the purpose of describing and discussing these developments, can, therefore, serve a very useful purpose.

"This first issue of Combustion reflects its editorial policy—to publish authoritative articles which will serve to keep all those interested in this field informed of what is being done and what the future trends are. The editorial pages of the magazine will be educational in a broad sense and helpful in a practical way. The authors will include men who are publicly recognized as the leaders of thought in their respective fields."

25th Anniversary Issue

As a contribution to the utility industry's campaign to publicize "Light's Diamond Jubilee," Combustion Engineering has published this advertisement in current issues of Fortune and Business Week.

Pearl Street Station, New York, built in 1882
(pictures courtesy Thomas Alva Edison Foundation)

Dynamo Room

Boiler Room

Birthplace of AMERICA'S INDUSTRIAL MIGHT

Though the machine age had existed for more than a century, Edison made it come of age. From his invention of the practical incandescent lamp in 1879 he went on to erect one of the most important industrial structures ever built—the Pearl Street central power station. This station was the forerunner of an industry which, as a source of light and power, changed the whole course of world development.

Electricity really began to make itself felt in America about 1900. By then, the average manufacturing worker had gained the electrical equivalent of two tireless helpers. *Today, the equivalent of 240 men help him on his job.* In this one dramatic fact is the underlying reason for our vast production capacity and high living standards.

Progress—both in efficiency and capacity—since the days of Pearl Street borders on the fantastic. For example, a turbine-generator is now being built which will have more than 2,000 times the capacity of one of the Pearl Street dynamos. And the C-E Boiler which will supply steam to this giant will be as high as a 15-story building—with a total volume greater than that of the entire Pearl Street Station and Edison's Menlo Park Laboratory combined.

This C-E Boiler, furthermore, will use less than ¾ of a pound of fuel to produce a kilowatt-hour of electricity, compared with 10 pounds at Pearl Street. To illustrate the significance of this achievement, suppose all the power in this country today were generated at Pearl Street's efficiency. Then, utilities would have consumed 2.4 *billion* tons, instead of the 178 *million* tons actually used in 1953. At present day fuel prices, this would have meant additional fuel costs of 17.7 *billion dollars*.

In this year of celebration of Light's Diamond Jubilee, Combustion Engineering—long associated with progress in power generation—is proud to pay tribute to the great and growing electric utility industry on the 75th anniversary of the invention that made it all possible.

B-749

C-E

COMBUSTION ENGINEERING

Combustion Engineering Building • 200 Madison Avenue, New York 16, N. Y.

BOILERS, FUEL BURNING & RELATED EQUIPMENT; PULVERIZERS, AIR SEPARATORS & FLASH DRYING SYSTEMS; PRESSURE VESSELS; AUTOMATIC WATER HEATERS; SOIL PIPE

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 26 **No. 1**

JULY 1954

Feature Articles

Editorials

Departments

COMBUSTION publishes its annual index in the June issue and is indexed regularly by Engineering Index, Inc.

GERALD S. CARRICK
Business Manager

JOSEPH C. McCABE
Editor

GLENN R. FRYLING
Associate Editor

CARL G. UDELL
Circulation Manager

Published monthly by COMBUSTION PUBLISHING COMPANY, INC., 200 Madison Ave., New York 16
A SUBSIDIARY OF COMBUSTION ENGINEERING, INC.

Joseph V. Santry, Pres.; Charles McDonough, Vice-Pres.; Otto Strauss, Treas.; Irving B. Swigart, Secy.
COMBUSTION is sent gratis to engineers in the U. S. A. in charge of steam plants from 500 rated boiler horsepower up and to consulting engineers in this field. To others the subscription rate, including postage, is $4 in the United States, $4.50 in Canada and Latin America and $5 in other countries. Single copies: Domestic, 40 cents; Foreign, 40 cents plus postage.

Publication Office, Easton, Pa. Issued the middle of the month of publication.
Acceptance under Section 34.64, P. L. & R., authorized by United States Post Office.

BPA

Printed in U. S. A.

Don't GAMBLE on Dust Collection Equipment

It pays to be sure of the results before you buy. That's why Buell takes such special care in the examination of each dust collection problem. Twenty years of experience has taught our engineers to predict results in advance. Before you spend a single penny!

Such thorough service, combined with Buell's unique dust collection equipment, is paying off for many of America's leading utilities and power plants.

We invite you to see an actual working demonstration of the new Buell Electric Precipitators—the most modern method of dust collection.

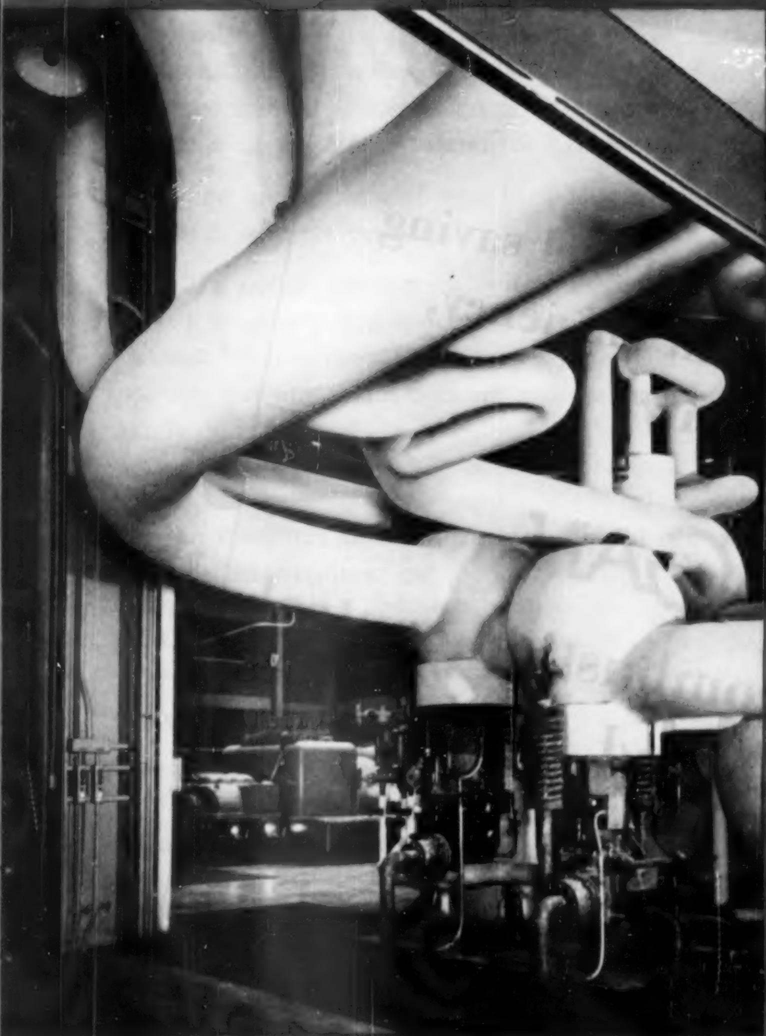
Using them singly and in combination systems we have achieved amazing performance records. We invite you to look at these records, compare results. Don't settle for less than the best. It never pays to gamble! Write for our informative Brochure—The Collection and Recovery of Industrial Dusts. It's free! Write Dept. 70-G, Buell Engineering Company, 70 Pine Street, New York 5, New York.

buell

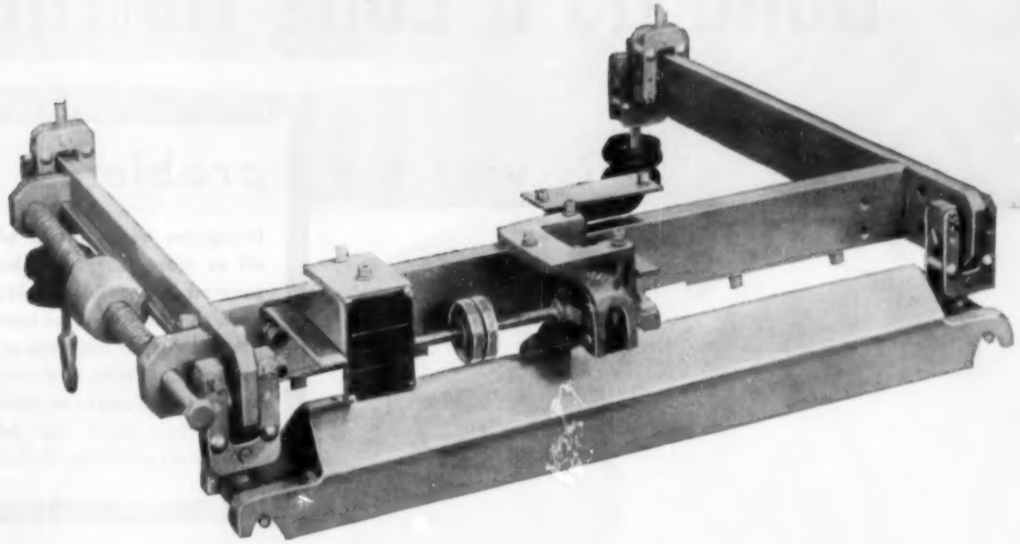
MECHANICAL ELECTRICAL

20 Years of Engineered Efficiency in

DUST COLLECTION SYSTEMS



Specification



Attention to Detail is the Reason Why

whatever you buy from Stock Equipment Company is of the highest quality. Take the weigh lever system illustrated above, for example. Top performance is assured because careful attention to design detail utilizes a non-welded steel assembly with steel loops. Hardened steel pivots and bearings in this lightweight unit mean low inertia and faster action with resultant greater accuracy.

Dust-Tight Slip Joint Connections between CONICAL Distributor and stoker hopper with drive gate to shut off the flow of coal to any individual stoker hopper section.

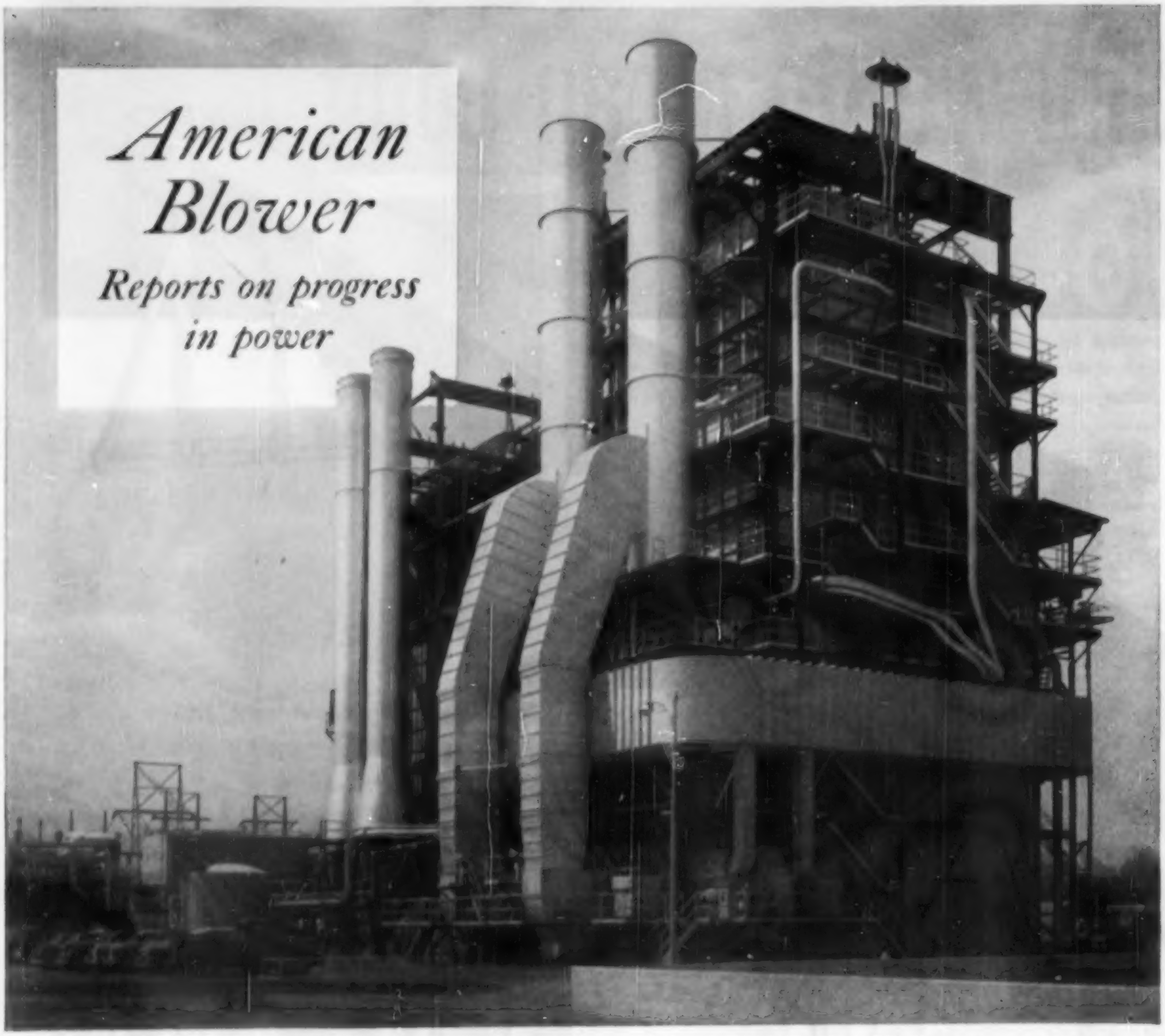
No matter if it's the design of a pivot in a weigh lever system, the layout of the overall job of delivering and weighing coal between bunker and pulverizer, or the fit of a dust-tight slip joint connection (as illustrated to the left), Stock Equipment Company takes time to make sure that it is right. This attention to detail means a completely satisfactory and overall economical job for its customers.

Pride of workmanship is a common attribute of all S-E-Co. employees and is reflected in all items of their manufacture, which include the S-E-Co. Coal Valve, Soot or Sifting Valve, Automatic Coal Scale, CONICAL Non-Segregating Coal Distributor, Automatic-Under-Bunker Conveyor, and Paddle Type Coal Alarm. Next time you need such equipment, why not enjoy the advantages of having the best?

STOCK EQUIPMENT COMPANY
745-C HANNA BUILDING
CLEVELAND 15, OHIO

Specialists in Bunker to Pulverizer and Bunker to Stoker Equipment


and we do mean Long"
VULCAN
KNOW-HOW
COSTS MORE
—But is Worth it
Soot BLOWERS



Up-to-date Ninemile Point Plant, near New Orleans, will have 310,000 kw capacity, when a third steam generating unit is completed in 1955. LP&LC's other steam-electric plant, Sterlington Station, has 146,000 kw capacity.

Louisiana Power installs the first

American Blower plays an important role in the LP&L Co. expansion program

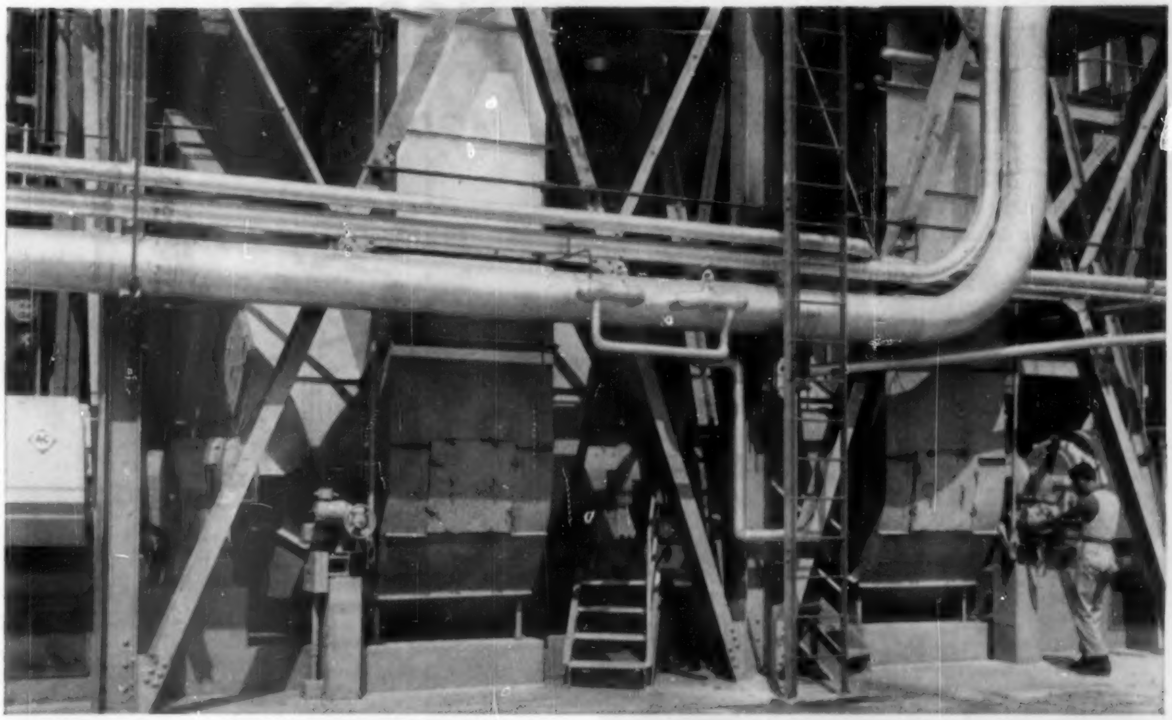
Scheduled for completion in early 1955, the third unit of Louisiana Power & Light Company's Ninemile Point Plant will be the first gas-fired unit in the country to employ the reheat cycle. By re-heating steam in the boiler after it has done part of its work in the turbine, the reheat cycle promises fuel savings and greater operating efficiency!

The new unit will boost capacity at Ninemile Plant to 310,000 kw. Its boiler will stand 14 stories high, have a high-speed elevator for rapid access to all operating levels and will be capable of producing 1,000,000 lbs. of steam per hour at a pressure of 1,525 pounds per square inch at 1,005° F.

Another unique feature at Ninemile Point Plant will be the commercial use of television for supervising the burning of natural gas in the boiler furnace. The control room operator will be able to light, adjust and control the furnace gas burners without leaving his station!

American Blower Forced and Induced Draft Fans

Serving home and industry: **AMERICAN-STANDARD • AMERICAN BLOWER • CHURCH SEATS & WALL**



Two American Blower Induced Draft Fans are installed in the Ninemile Point Plant. Each has capacity of 143,500 cfm at 695 rpm with 8.3" sp. Driving power required is 319 hp.

This is one of two American Blower Forced Draft Fans at the Ninemile Point Plant. Each has a capacity of 78,000 cfm at 9.07" sp when operating at 1160 rpm requiring 164 hp.

gas-fired unit with reheat cycle!

have played an important part in LP&LC's expansion program. American Blower also makes Dust Collecting Equipment, Fly Ash Precipitators and Gýrol Fluid Drives for boiler feed pump and fan control.

If you plan to modernize or expand your facilities, talk over your problems with any American Blower engineer. His knowledge of the application of air-handling equipment and Gýrol Fluid Drives can prove invaluable to you. Contact your nearest American Blower Branch Office, or write us direct.

AMERICAN BLOWER CORPORATION, DETROIT 32, MICHIGAN
CANADIAN SIROCCO COMPANY, LTD., WINDSOR, ONTARIO
Division of American Radiator & Standard Sanitary Corporation

AMERICAN BLOWER

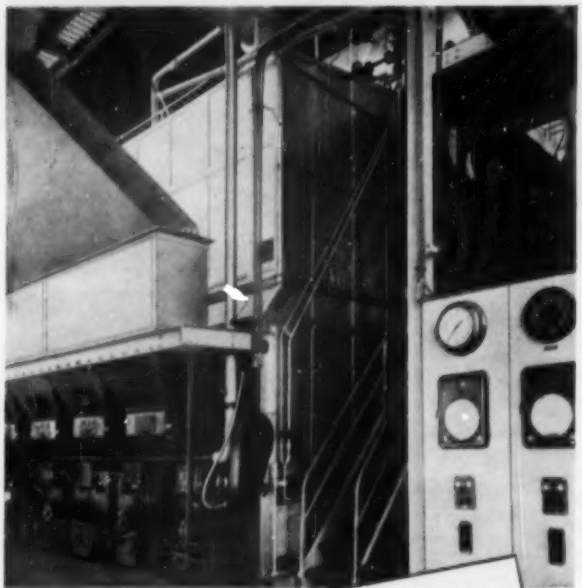
TILE • DETROIT CONTROLS • KEWANEE BOILERS • ROSS EXCHANGERS • SUNBEAM AIR CONDITIONERS

"HOW WE SAVE MORE THAN $90,000 A YEAR—

BY BURNING COAL THE MODERN WAY!"

says W. H. FISHER, Plant Engineer, Kerr Bleaching and Finishing Works, Concord, North Carolina.

"Powering our plant used to take nine boilers—now *one* does the same job *using 30% less fuel!* 6 firemen now do the work of 18—thanks to modern coal-handling equipment and automatic controls. That's why we say, you can't beat bituminous coal burned with modern equipment."



Above is a view of the plant's modern, space-saving coal-storage silo. To the left is a close-up of the firing aisle, showing the spreader stoker and the main control panel. Coal handling is automatic and dust-tight throughout. Automatic controls regulate firing, drafts and feed-water—give maximum efficiency at lowest cost.

If you operate your own steam plant, you can't afford to ignore these few down-to-earth facts!

COAL in most places is today's lowest-cost fuel.

COAL resources in America are adequate for all needs—for hundreds of years to come.

COAL production in the U. S. A. is highly mechanized and by far the most efficient in the world.

COAL prices will therefore remain the most stable of all fuels.

COAL is the safest fuel to store and use.

COAL is the fuel that industry counts on more and more—for with modern combustion and handling equipment, the inherent advantages of well-prepared coal net even bigger savings.

Burning coal the modern way can save *you* money, too! First, labor costs can be cut to a minimum with up-to-date coal- and ash-handling equipment. On top of that, today's combustion installations give you 10 to 40% more power from each ton of coal than was possible a few years ago!

If you're planning to modernize, or if you're building a new plant, call in a consulting engineer. He'll show you how you can get big savings by burning coal in a modern plant designed to meet your *specific* needs.

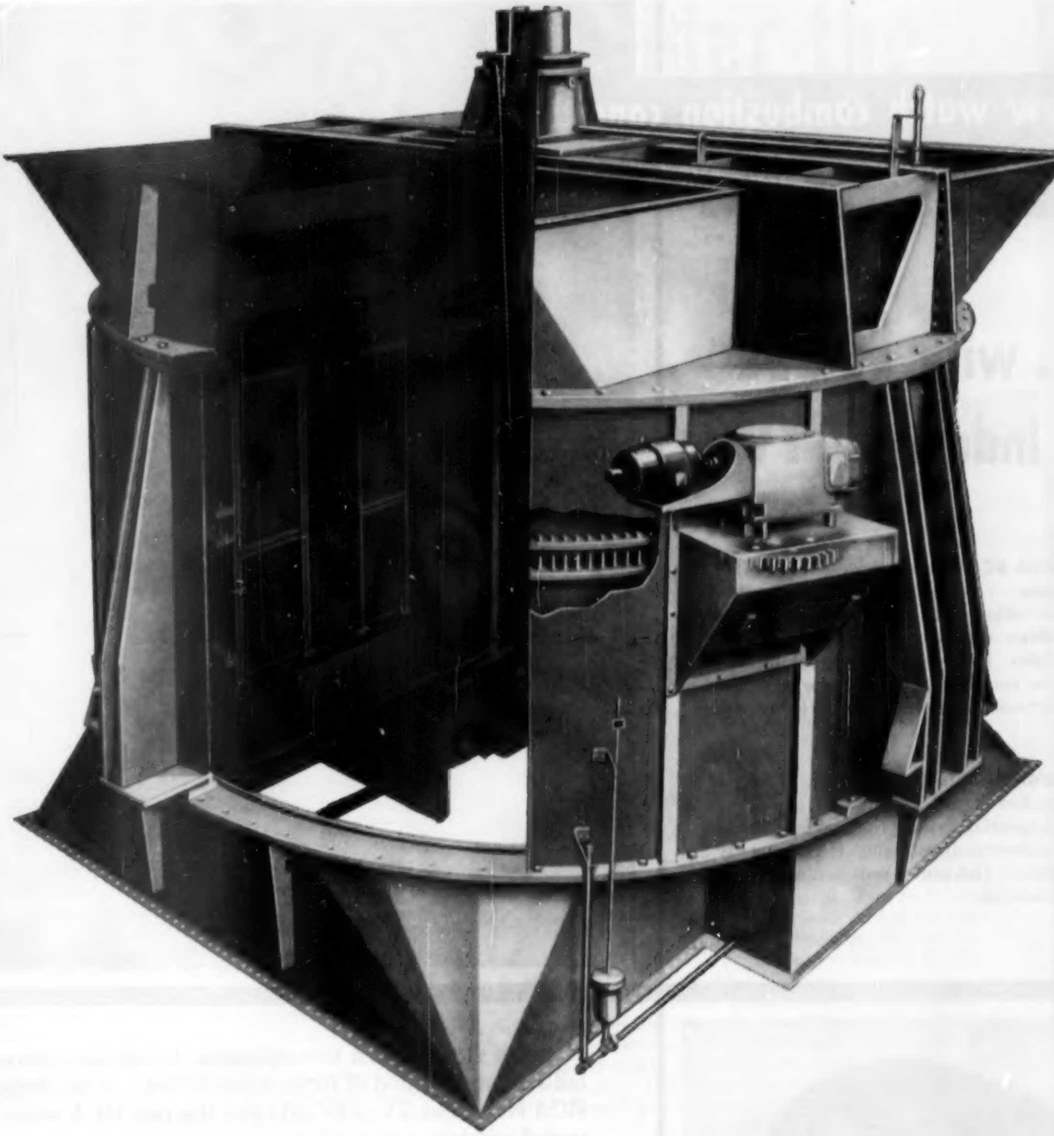
America's coal reserves are virtually inexhaustible; America's coal industry is the world's most productive and efficient. That's why coal has a future dependability of supply that no other fuel can offer. That's why, of all fuels, the price of coal is most likely to remain stable.

BITUMINOUS COAL INSTITUTE

A Department of National Coal Association, Washington, D. C.

FOR HIGH EFFICIENCY • FOR LOW COST

YOU CAN COUNT ON COAL!



THE LJUNGSTROM AIR PREHEATER

cuts fuel costs in hundreds of plants

The Ljungstrom Air Preheater has proved its value in industrial and utility plants throughout the country. That's why every year, a constantly increasing percentage of the total installed boiler capacity is Ljungstrom-equipped. *Your fuel costs will drop, too,* when you equip your boilers with Ljungstroms. The extremely high efficiency of the regenerative design means the greatest possible recovery of waste heat . . . with substantially lower fuel requirements. If you are planning a new boiler installation — or expanding or modernizing your present one — let our engineers show you how the Ljungstrom can raise over-all efficiency in your plant. Ljungstrom Air Preheaters are now available for boilers of any type or capacity from 25,000 pounds of steam per hour up.

The Air Preheater Corporation 60 East 42nd Street, New York 17, N. Y.

Now watch combustion conditions every minute of the day

. . . with RCA Industrial TV

With RCA's new water-cooled window—you maintain continuous observation of flame conditions and ignition—*at the control panel*—24 hours a day. High-detail picture eliminates the need for periodic observation of furnace and checking burner operation.

Water-cooled window can be installed at top of furnace to observe tangential firing—in side of furnace to observe direct firing. High-capacity blower and pump unit can serve two windows.

HERE'S THE ANSWER to continuous, low-maintenance, fail-safe observation of furnace conditions . . . high-detail RCA Industrial TV (ITV-5A) and the new RCA water-cooled window.

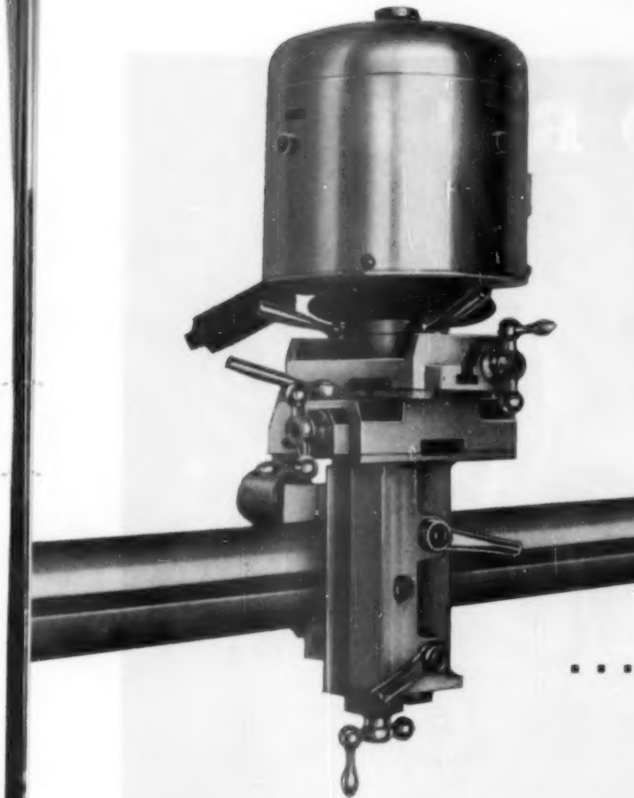
By using a high-efficiency circulating system, RCA has reduced lens temperatures at the camera below 120° F—for stable, dependable camera operation.

The RCA Industrial TV water-cooled window is a reliable tool for use by your operators for continuous remote observation of combustion conditions. RCA now offers this new revolutionary equipment as a complete, engineered package to power plants—plus installation and maintenance service.

FOR INFORMATION on RCA Industrial TV (Type ITV-5A), write Radio Corporation of America, Dept. G-187, Building 15-1, Camden, New Jersey.

INDUSTRIAL PRODUCTS
RADIO CORPORATION of AMERICA
ENGINEERING PRODUCTS *CAMDEN, N.J.*

In Canada: RCA VICTOR Company Limited, Montreal



Consider the low cost of model testing

. . . when critical piping is the order!

Mechanical engineers are quite familiar with the fact that today's high operating temperatures may produce severe expansion stresses and reactions in high temperature power piping systems. But the accurate determination of these by analytical methods can involve extremely complicated and tedious mathematics.

A proved means for eliminating much of the expense of this essential engineering is the Kellogg Model Tester. This device's patented electrical measuring heads (illustrated), together with its servo-operated electronic equipment, enable Kellogg engineers to make complete analyses of thermal effects including line movements . . . at low cost.

For very complicated piping systems, the model tester is the only practical method of obtaining accurate solutions. For simpler systems, it serves as a relatively inexpensive check on calculated results. Furthermore, once the permissible reactions are established for loadings at the throttle valve and the superheater header connections, the optimum design for the remainder of the system can be developed without removing the model from the tester. For analyses of less complicated piping systems, Kellogg engineers employ a modern IBM computer to reduce costs and time required to arrive at results.

Well-conceived support and anchor designs for the suspension and expansion control of all classes of lines are readily established from the information furnished by the model tester. It can also provide data to insure proper handling of the piping in the field, during welding and heat treating . . . minimizing strains, due to extraneous loadings, which might be detrimental to the production of soundly welded joints.

This approach to the problems of critical power piping—the development of new and improved methods, of less expensive methods—is Kellogg's basic stock in trade. Many power station designers and utility companies also say it's the basic reason why they repeatedly specify *"critical power piping by Kellogg."*

* * * *

NEW POWER PIPING BOOKLET . . . Send for descriptive literature about Kellogg's extensive facilities for assuring the highest quality workmanship.

These leading companies are among the many major producers of power who use M. W. KELLOGG POWER PIPING . . .

- Hartford Electric Co.
- Houillers Du Lorraine (France)
- Houilleres Du Bassin Du Nord Et Du Pas-De-Calais (France)
- Hydro-Electric Power Commission of Ontario (Canada)
- Indiana & Michigan Electric Co.
- Long Island Lighting Co.

OTHER FABRICATED PRODUCTS include: Pressure Vessels . . . Vacuum Vessels . . . Fractionating Columns . . . Drums and Shells . . . Heat Exchangers . . . Process Piping . . . Bends and Headers . . . Forged and Welded Fittings

For further information, details of methods, etc. contact

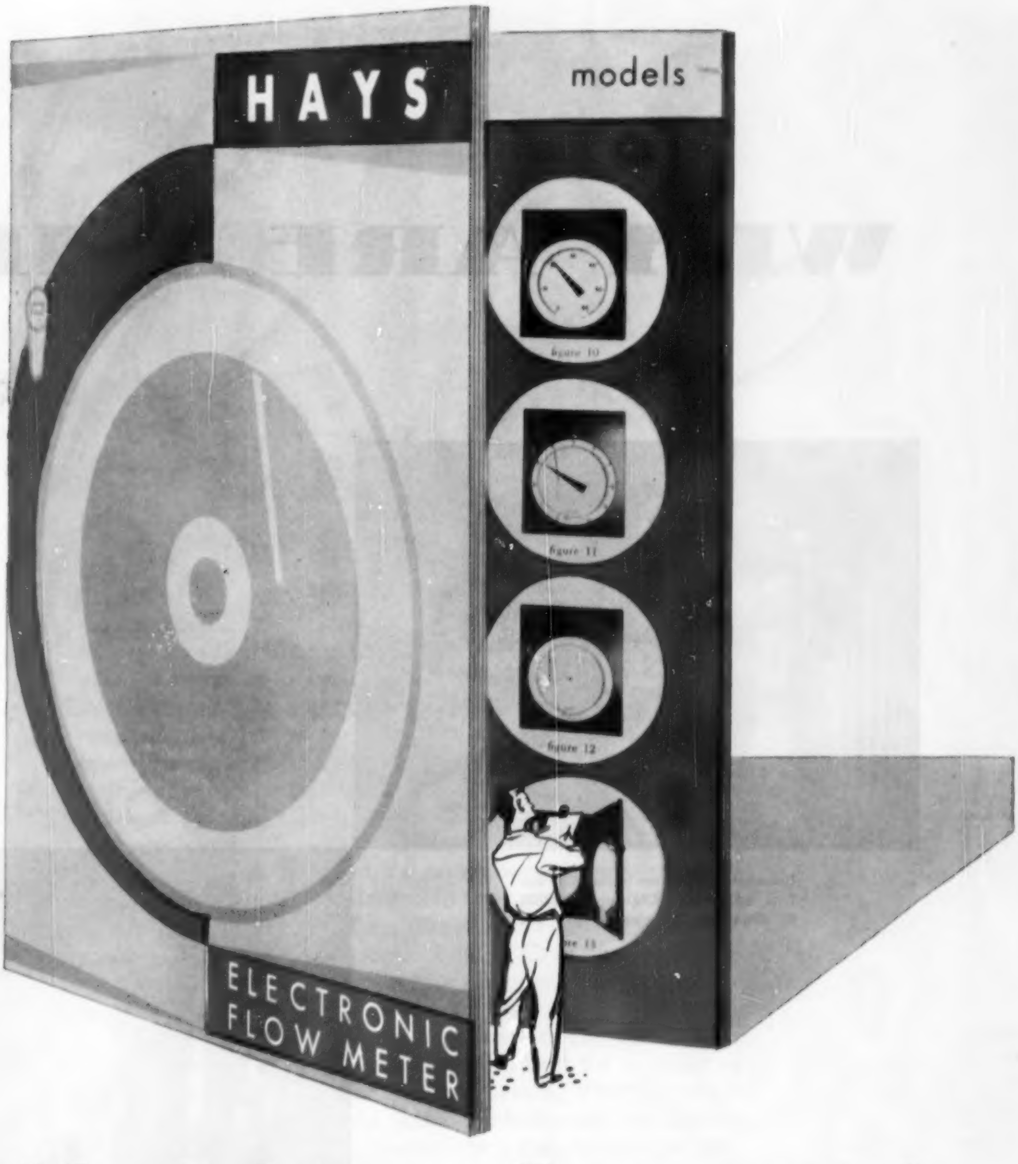
FABRICATED PRODUCTS DIVISION

THE M. W. KELLOGG COMPANY

225 Broadway, N. Y. 7, N. Y.
also Jersey City, Buffalo, Birmingham, Chicago, Los Angeles, Tulsa, Houston
In Canada—Toronto and Edmonton
In Europe—London and Paris

KELLOGG — Subsidiary of PULLMAN Incorporated

KELLOGG
HIGH TEMPERATURE
HIGH PRESSURE
POWER PIPING
KELLOGG
HIGH TEMPERATURE
HIGH PRESSURE
POWER PIPING
KELLOGG
HIGH TEMPERATURE
HIGH PRESSURE
POWER PIPING
KELLOGG
HIGH TEMPERATURE
HIGH PRESSURE
POWER PIPING



A guide to better flow metering

Here's a new fact-filled, technical booklet that tells you feature for feature how the new Hays electronic flow meter excels.

Electronic operation—provides maximum accuracy (¼% of full scale differential), and speed (4 seconds for full scale pen travel).

Mercuryless transmitters—rupture-proof metallic bellows for differential pressure measurement.

Continuous integration—motor-driven, continuous mechanical integrator is extremely accurate even on rapid load changes.

Other features include powerful motor, easy readability, accuracy unaffected by normal temperature changes, optional explosion and weather-proof transmitter.

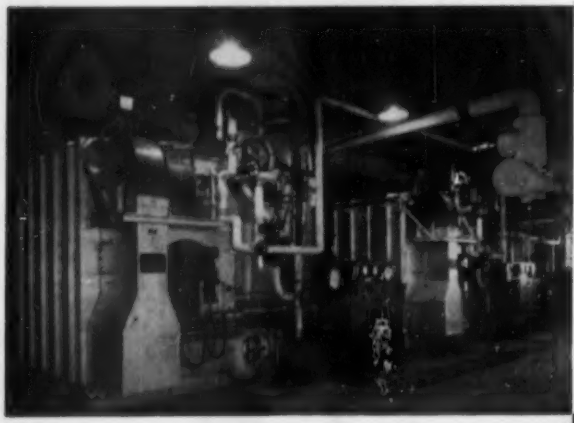
Write for bulletin 54-1074-222 and get the important facts.

Automatic Combustion Control
Boiler Panels • CO_2 Recorders
Veriflow Meters and Veritrol
Gas Analyzers • Draft Gages
Combustion Test Sets
Electronic Oxygen Recorders
Electronic Flowmeters
Electronic Feed Water Controls
Miniature Remote Indicators

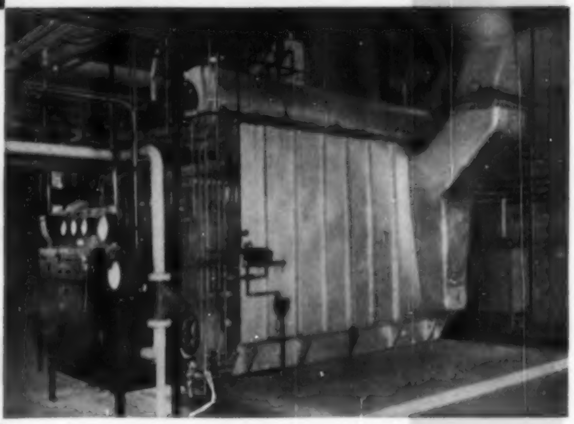
THE **hays** CORPORATION

MICHIGAN CITY, 1, INDIANA

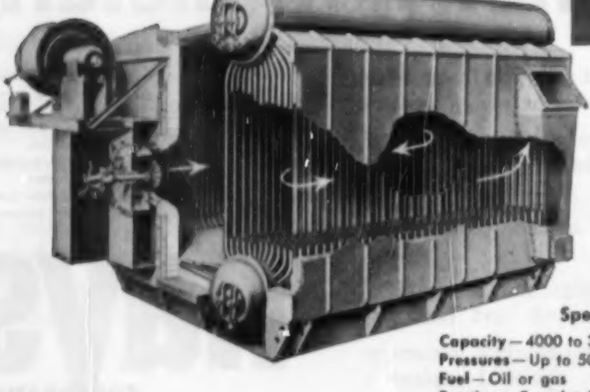
WHY ARE THEY



Industrial installation in the Midwest. Two VP Boilers. Capacity — 28,000 lb steam per hr each at 225 psi.



This VP Boiler serves a sewer pipe manufacturer in California. Capacity — 20,000 lb steam per hr at 215 psi.



Specifications — VP Boiler

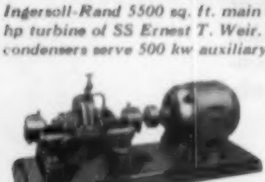
Capacity — 4000 to 30,000 pounds of steam per hour
Pressures — Up to 500 pounds per square inch
Fuel — Oil or gas
Erection — Completely shop-assembled
Foundation — Simple concrete slab

ERNEST T. WEIR

largest ship ever built on fresh water

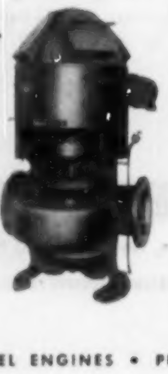
SERVED BY I-R CONDENSERS AND PUMPS

Ingersoll-Rand 5500 sq. ft. main condenser for 7,000 hp turbine of SS Ernest T. Weir. Two 600 sq. ft. I-R condensers serve 500 kw auxiliary turbine.



I-R Class GT condensate pump for auxiliary condenser.

I-R 75 hp Class VCM circulating pump for main condenser.



One of two I-R Class VHM 15 hp condensate pumps for main condenser.

The SS Ernest T. Weir, built by American Ship Building Co., has an overall length of 690 feet, 70-ft. beam and a draft of 25½ ft. – making her the largest vessel so far built on fresh water. A recent addition to National Steel's great ore-carrying fleet, she has a deadweight carrying capacity of 21,948 long tons.

This new ore carrier carries some important items of Ingersoll-Rand equipment – equipment that contributes to the smooth functioning and dependability of her power plant – main condenser with air ejector, circulating and condensate pumps; two auxiliary condensers with air ejectors and condensate pumps; also fire and general service pumps and cooling water pump.

Seagoing power plants of all sizes can be served to advantage by *dependable* I-R pumps, condensers and auxiliaries. Your I-R representative will be glad to assist you in any way he can.

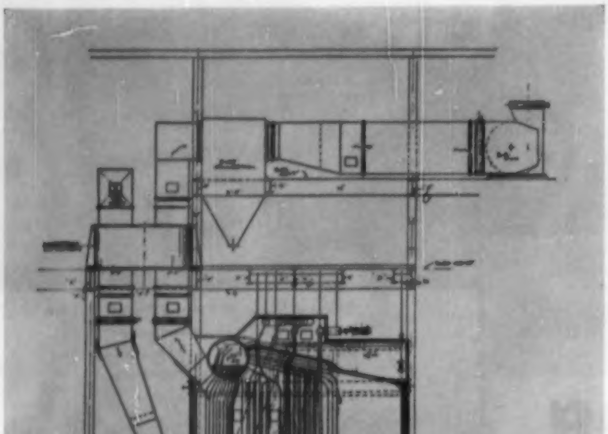
Ingersoll-Rand

11 Broadway, New York 4, N. Y.

4-67

AIR AND ELECTRIC TOOLS • DIESEL ENGINES • PUMPS • CONDENSERS • COMPRESSORS • VACUUM EQUIPMENT

NEW IOWA ELECTRIC LIGHT AND POWER COMPANY PLANT EQUIPPED WITH



New Iowa Electric Light and Power Company Sutherland Station at Marshalltown, Iowa. This is a 300,000 pounds of steam per hour Riley steam generating unit. Design pressure 975 with steam temperature 910°F. Operation is scheduled for fall, 1954. Duplicate unit will be ready in 1955.

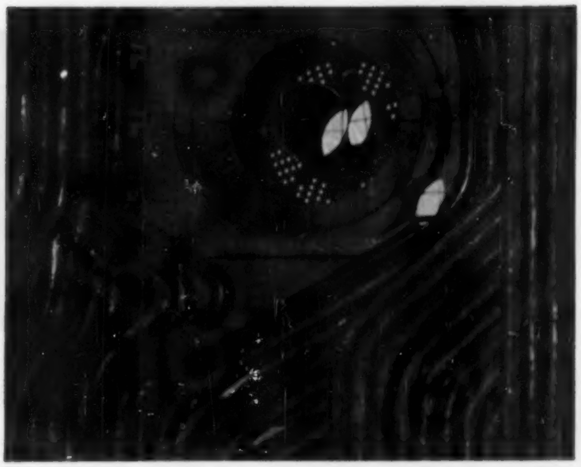
TO HELP MAKE SURE they get the power they've bought, this Midwest utility has a new plant equipped with Republic ELECTRUNITE Boiler Tubes.

One reason is dependability. ELECTRUNITE Boiler Tubes are made from high grade steel, produced in Republic's own mills. From the time the ore is mined, through manufacturing stages, operations are quality controlled.

The results: Tubes with uniform wall thickness which give uniform heat transfer, all around the tube, from end to end. Uniform ductility for

Some Recent ELECTRUNITE Boiler Installations

Edwardsport Station, Public Service Co. of Indiana
National Petro-Chemicals Co., Tuscola, Ill.
Municipal Light Plant, Orville, Ohio
B. F. Goodrich Co., Akron, Ohio
Capitol Power Plant, Washington, D. C.
Riegel Textile Corp., Trion, Georgia
Superior Water, Light and Power Co., Superior, Wis.
Ford Motor Co., Dearborn, Mich.
Murray-Ohio Manufacturing Co., Cleveland, Ohio
Central Ohio Light & Power Co., Findlay, Ohio
International Harvester Co., Chicago, Ill.
Sloane-Blabon Corp., Trenton, N. J.
Mid-Continent Petroleum Corp., Tulsa, Okla.
Swift & Co., Hammond, Ind.
City of Provo, Provo, Utah
Kennecott Copper Corp., Hayden, Ariz.
Missouri Power & Light Co., Mexico, Mo.
Gilbert Paper Co., Menasha, Wis.
Morton Salt Co., Manistee, Mich.



Uniform ductility of Electrunite *Boiler Tubes permits accurate bends to be made easily. Spring-back can be calculated before the bending operation.*

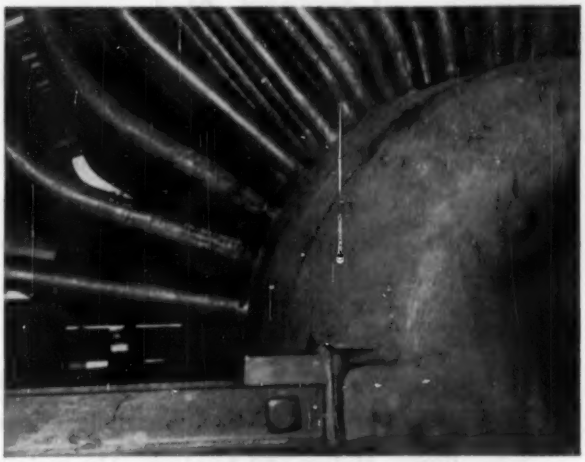
ELECTRUNITE

BOILER TUBES

smooth bending and smooth roller expanding.

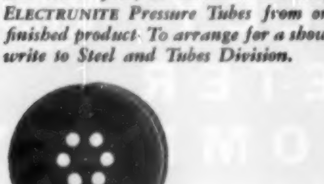
Electrunite Boiler Tubes also pay off from the standpoint of economics. Before you plan your next power expansion, or modernization, consider Republic Electrunite Boiler, Condenser and Heat Exchanger Tubes. Write for the booklet CEC-54 which gives you complete data and specifications.

REPUBLIC STEEL CORPORATION
Steel and Tubes Division
209 E. 131st Street, Cleveland 8, Ohio
GENERAL OFFICES • CLEVELAND 1, OHIO
Export Department: Chrysler Building, New York 17, N. Y.



Surfaces of Electrunite *Boiler Tubes are scale-free because they are normalized in a controlled atmosphere. No grinding tube ends, which destroys uniformity. Tubes slide into drum holes easily, expand uniformly.*

"Intestinal Fortitude"—16mm. sound, black and white film, 17 minutes. The story of Electrunite *Pressure Tubes from ore to finished product. To arrange for a showing, write to Steel and Tubes Division.*



Republic
REPUBLIC STEEL
ELECTRUNITE
BOILER, CONDENSER AND HEAT EXCHANGER TUBES

Companions IN RELIABLE SERVICE...

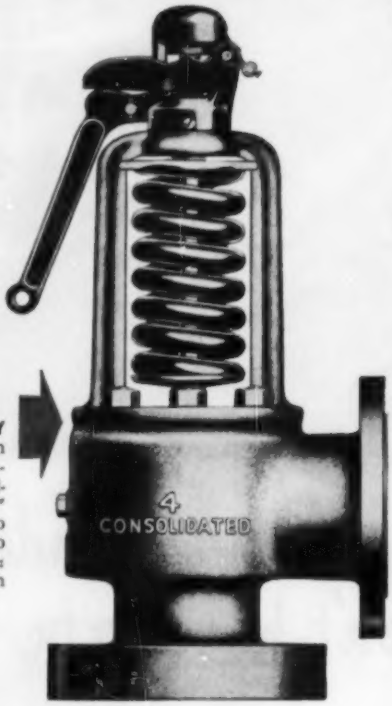
TYPES 1411 and 1415 CONSOLIDATED SAFETY VALVES

TYPE 1411

CAST IRON BODY SAFETY VALVE. Has bevel seat, single ring blow-down control and one-piece feather (disc). **Sizes:** 1½" through 6". **Pressures:** Up to 250 psi. **Temperatures:** Up to 450° F. **Standard Connections:** Threaded or flanged. All sizes available with oversize inlet flanges for replacement purposes.

TYPE 1415

CAST STEEL BODY SAFETY VALVE. Has a high erosion and corrosion-resistant stainless steel seat bushing **seal-welded to the base. Sizes:** ½" through 6". **Pressures:** Up to 900 psi. **Temperatures:** Up to 900° F. **Standard Connections:** Flanged. Available with oversize inlet flanges.



Dependable performance in hundreds of installations is the history of Consolidated Safety Valves Types 1411 and 1415. Time and time again, the high discharge capacity of these rugged valves has been thoroughly proved in the field. Positive, tight closing after operation is assured. Both types are simply constructed spring-loaded, wing-guided valves with few working parts. Adjustment is easy; maintenance economical.

Type 1411, with cast iron body, is excellent for installation on water tube boilers, mechanically-fired fire tube boilers, accumulators, unfired pressure vessels and pipe lines within its rated capacity. Types 1415, with cast steel body, is recommended for all applications beyond the scope of companion valve Type 1411.

Protect your personnel, facilities and production against the hazards of over-pressures. Install precision-built Consolidated Safety Valves. Selection is easy. Write for Catalog 700.

1879 CONSOLIDATED U.S.A.

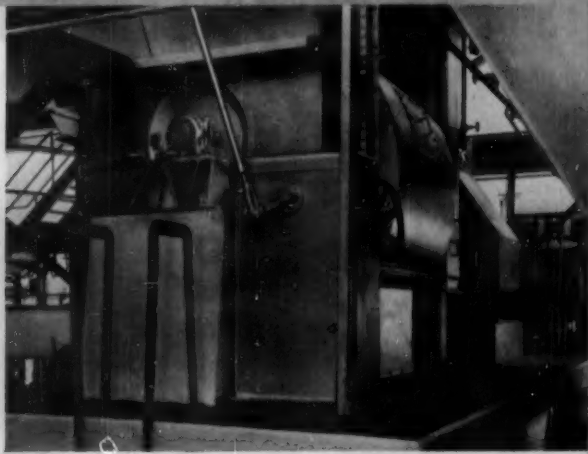
CONSOLIDATED SAFETY VALVES

A product of **MANNING, MAXWELL & MOORE, INC.** STRATFORD, CONN.

MAKERS OF 'CONSOLIDATED' SAFETY AND RELIEF VALVES, 'AMERICAN' AND 'AMERICAN-MICROSEN' INDUSTRIAL INSTRUMENTS, 'ASHCROFT' GAUGES, 'HANCOCK' VALVES, AIRCRAFT PRODUCTS. BUILDERS OF "SHAW-BOX" AND 'LOAD LIFTER' CRANES, 'BUDGIT' AND 'LOAD LIFTER' HOISTS AND OTHER LIFTING SPECIALTIES.

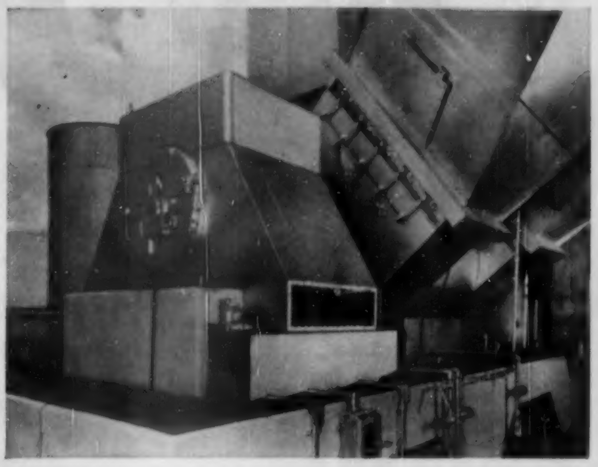
MAXWELL MM&M TRADE MARK


At Florida
Power & Light
Company's Beautiful
SARASOTA
PLANT
Combustion Air & Gases
GO
on
GREEN FANS



GREEN FORCED DRAFT FAN

A GREEN Forced Draft Fan installed at Sarasota. This Green Fan No. 56 RB 3615 BD is driven by a 200 HP Electric Motor, and delivers 79,800 CFM air at 100°F.



GREEN INDUCED DRAFT FAN

This GREEN Induced Draft Fan delivers 132,000 CFM of Gas at 365°F at the Sarasota Plant. It is Green Fan No. 51 MC 3202 D and is driven by a 400 HP Electric Motor.

Keeping pace with the demand for more power occasioned by the tremendous growth of Florida's population and industry, Florida Power & Light Company is now engaged in a $332,000,000, ten-year expansion program. One phase of this program is the expansion of the Sarasota Plant.

When it came time to specify forced and induced draft fans for Sarasota, they picked GREEN. F. P. & L. has operated GREEN FANS in other plants in its system for a number of years.

There are hundreds of other similarly satisfied customers throughout the country.

Send for our Fan Bulletin 168. If interested in Fuel Economizers ask for Bulletin 169. Our Aerodyne Dust Collectors are described in Bulletin 170. All are yours for the asking.

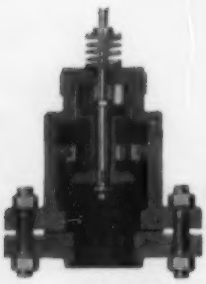
The Green Fuel Economizer Company, Inc.

BEACON 3, NEW YORK

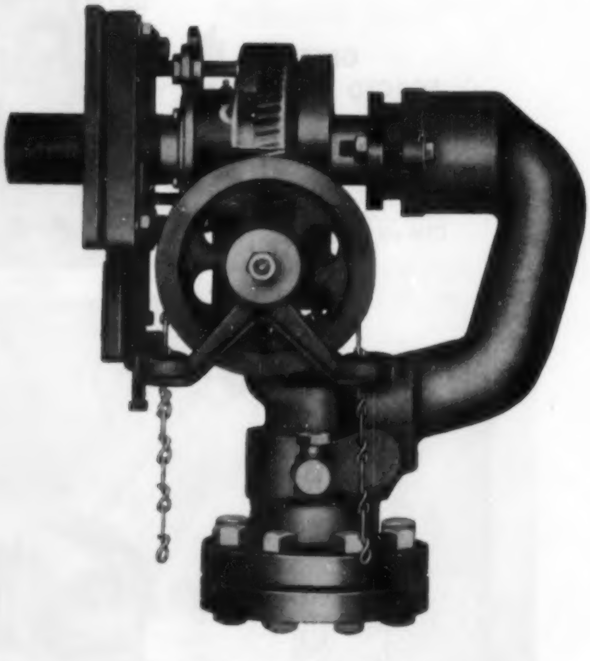
ECONOMIZERS • FANS • AIR HEATERS • CINDERTRAPS • AERODYNE DUST COLLECTORS

BAYER
STEPS UP BOILER PERFORMANCE

DISTINCTLY DIFFERENT



Bayer Balanced Valves are famous for their long life and continued tightness.



Bayer Single Chain Balanced Valve Soot Cleaner.

WITH THE Bayer Balanced Valve Soot Cleaner the balancing chamber above the piston disc impounds steam when the valve closes, thus relieving valve parts from shock. The valves remain ***steam tight*** because the dashpot action causes the valve to seat gently. Unbalanced valves close with a hammer stroke and soon become leaky.

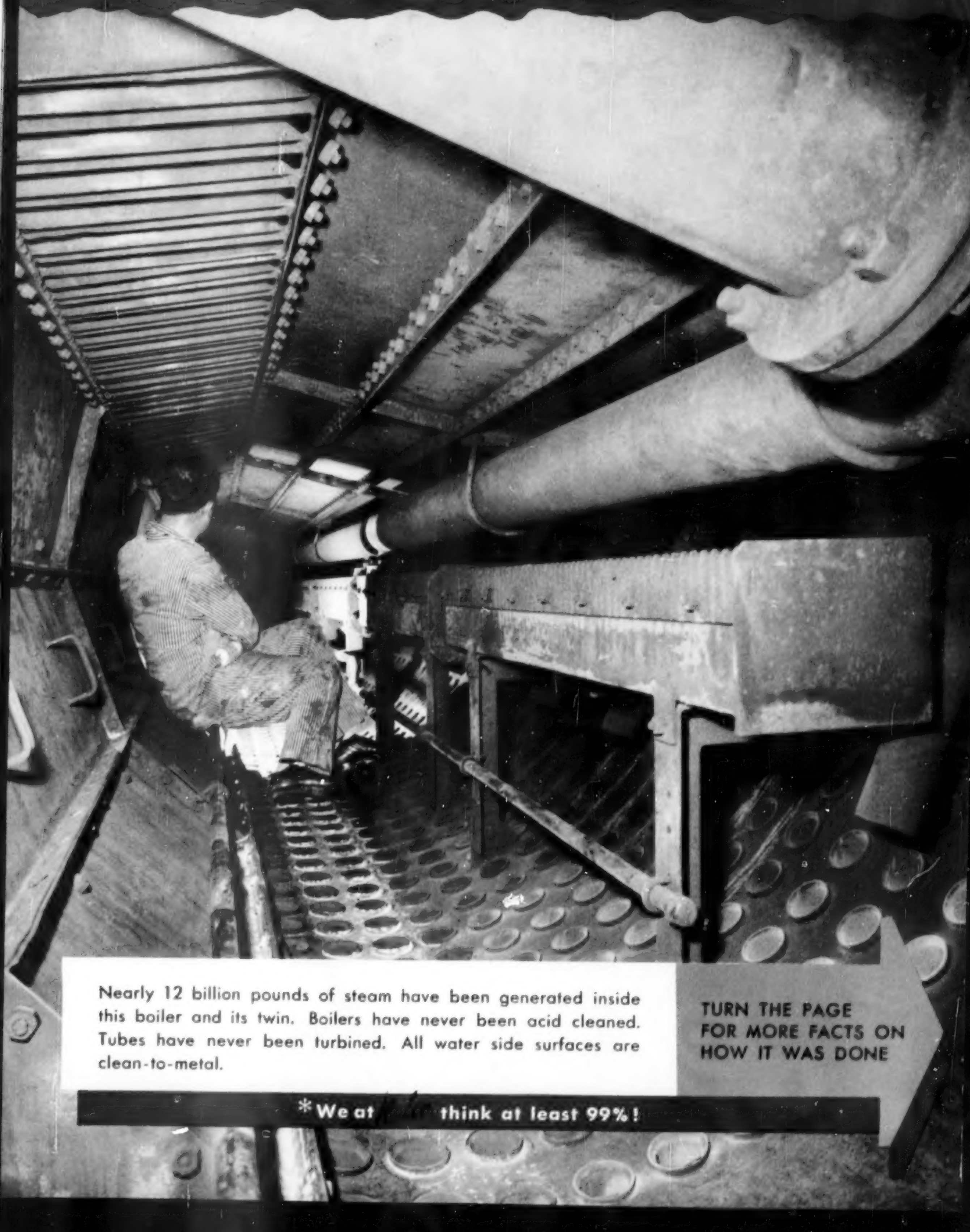
When stationary elements are used the Bayer stationary balanced valve head may be furnished. Thus all the cleaning elements of the entire soot cleaner system can be controlled by the Bayer quick-opening Balanced valves. This gives a uniform or standard valve controlled system and in addition, when high pressures require a reduction in pressure *at each individual element* this Balanced valve unit, whether used with a stationary or a revolving element, can be fitted with an integral orifice plate valve.

Piping connections can be kept in the same plane and undesirable bends or fittings avoided when the Bayer Balanced Valve is installed with both stationary and revolving elements.

Valve parts are standard and interchangeable and when high pressure heads are fitted with orifice plate regulating valves these parts are also interchangeable.

THE BAYER COMPANY
SAINT LOUIS, MISSOURI, U. S. A.

Proof of PERFECT* Water Treatment PERFORMANCE



Nearly 12 billion pounds of steam have been generated inside this boiler and its twin. Boilers have never been acid cleaned. Tubes have never been turbined. All water side surfaces are clean-to-metal.

TURN THE PAGE FOR MORE FACTS ON HOW IT WAS DONE

*We at think at least 99%!

BOILER OPERATING DATA

● Two new boilers were put on line in a Southwestern municipal utility plant at the same time late in 1949. Rated capacity of each unit is 250,000 pounds of steam per hour at 950 p.s.i. Normal operating rates range from 150,000 to 175,000 pounds of steam per hour per unit.

The Nalco System of water treatment has been used continuously in these boilers. Raw water softening is by Nalcite* Ion Exchange Resins, and other Nalco products are used for after-treatment, internal treatment, and condensate return line protection. Results have been perfect. Boilers have never been turbined or acid cleaned, and are opened only for annual internal inspection.

*Registered Trademark

CLEAN . . . FOR TOP HEAT TRANSFER EFFICIENCY
What appear to be chalk marks in this unretouched photo are scrape marks which indicate only the usual powdery film left on the metal when the boiler is drained.

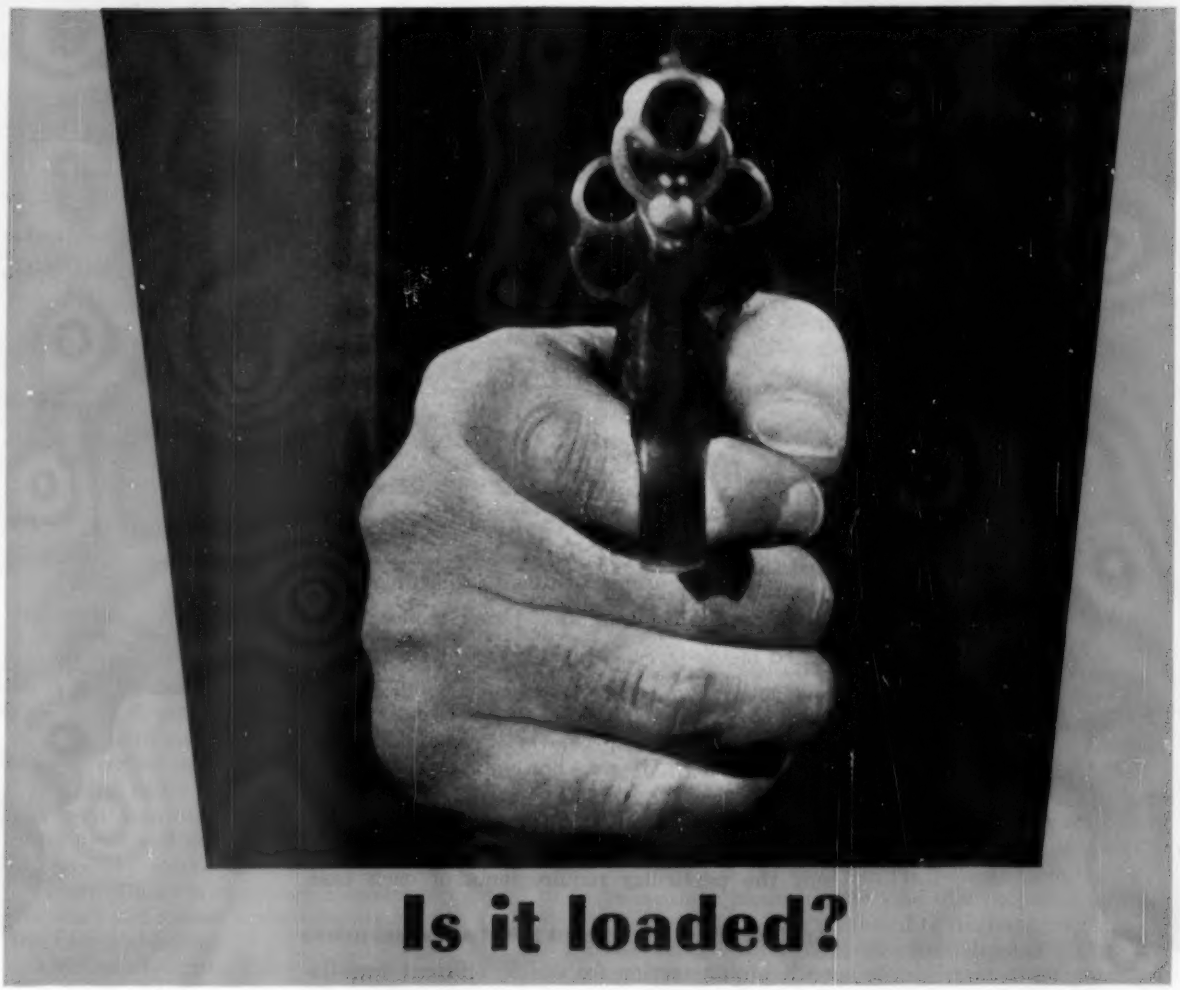
AND THE MUD DRUM IS SPOTLESS, TOO!
Another unretouched photo inside the mud drum of one of the boilers shows the like-new condition after years of service. No deposits or corrosion of any kind have been found in tubes or drums.

Nalco ON THE JOB

● Results like these are encountered every day in plants when the complete Nalco System of water treatment is on the job. The Nalco System is adaptable to old and new plants of any capacity, temperature, or pressure. Whether you operate a public utility or a space heating boiler, you will find your Nalco Representative of real assistance in the solution of your water treatment problems. Call him today, or write for full information.

NATIONAL ALUMINATE CORPORATION
6216 West 66th Place • Chicago 38, Illinois
In Canada: Alchem Limited, Burlington, Ontario

THE *Nalco*® SYSTEM . . . Serving Industry through Practical Applied Science


Is it loaded?

BEHIND

THESE

EYES

is your assurance of quality finishing in the fabrication of your piping. Using modern, perfected methods, Shaw's skilled technicians check and square your job for dimension, alignment, conformance to specified tolerances, accuracy of proper fitting. After a thorough cleaning inside and out, your job is metallurgically examined and ultrasonically and hydrostatically tested to suit the particular requirements of each case.

Another Shaw department then paints and marks each piping section for quick, efficient installation, and proper precaution is taken through protective devices to prevent damage to your product during shipment.

Carelessness in the testing and finishing stages of your piping fabrication can prove costly and time consuming. The trained and tireless eyes of skilled technicians in every department of Shaw's complete testing and finishing procedure are your assurance of a finished project that gives lasting, trouble-free performance—a product that conforms accurately to specifications. Buy the finest in modern quality control methods. Buy from Shaw; it pays—all ways.

BENJAMIN F.
SHAW
COMPANY
WILMINGTON, DELAWARE

COMBUSTION

Editorials

On Our Twenty-Fifth Anniversary

When Editor McCabe asked me to write an editorial for this issue—an invitation valued the more because of its infrequency—I suppose he had in mind that an anniversary issue was one occasion when a little reminiscing about the past and even a modicum of self-congratulation might be viewed indulgently by readers. Doubtless he was also motivated by the fact that the writer was the only member of the organization who had been around since COMBUSTION first saw the light of day back in July 1929.

Elsewhere in this issue, under the title "Gleanings From a Quarter Century of COMBUSTION," the editor pays tribute to some of the individuals who have made notable contributions to our columns during the years, and gives an eclectic summary of articles published on a variety of important subjects. Here, despite our disposition to talk a lot about the past, we shall content ourselves with giving brief recognitions to the men who have served on our editorial staff.

The first editor of COMBUSTION was Carl Stripe. He had been associated with Combustion Engineering for many years and was particularly qualified, both by experience and special talents, for the editorial duties he assumed. Under his guidance, COMBUSTION got off to a fine start and gained rapid recognition as an authoritative technical journal.

After nearly three years of service as editor, Mr. Stripe resigned to enter another field and the writer assumed the editorial reins. We were then in the depths of the great depression and COMBUSTION shared with virtually all other magazines, as well as with business generally, the problem of survival. In late 1933, Alfred D. Blake joined the staff and greatly lightened the burden of keeping going. In March 1934, he was made Associate Editor and in January 1935 he took over the full responsibilities of Editor.

Perhaps the best way to pay tribute to Al Blake's achievements as Editor of COMBUSTION is to quote the citation read at the time he was made a Fellow of the American Society of Mechanical Engineers in October 1952.

> "Alfred D. Blake is a graduate of Cornell University with an M.E. degree. He began his engineering career with Westinghouse, Church, Kerr, consulting engineers, was associate editor of *Power* and served in the United States Army during World War I with the rank of Major. After the war he returned to *Power* where he rose to managing editor. Later he served briefly as editor of *Steam Plant Engineering.* In 1933 he joined Combustion Publishing Company and has been editor of COMBUSTION since that time.
>
> Mr. Blake has guided the editorial policy of COMBUSTION so well that power engineers regard that publication as one of the outstanding technical journals in the world. Its articles have been authoritative and have made major contributions to technical development."

Glenn R. Fryling joined us as Assistant Editor in 1948. His articles and editorials during the past five years have occasioned much favorable comment, as have his reports of the many engineering society meetings he has covered. In January of this year he was made Associate Editor. At the same time, Joseph C. McCabe was appointed Editor, succeeding Mr. Blake. Mr. McCabe brought to his post the special qualification of having served as Associate Editor of our contemporary, *Power*, for the past eight years. Since the backgrounds and experience of both Mr. McCabe and Mr. Fryling were given fully in the announcement of Mr. Blake's retirement in our December 1953 issue, they will not be repeated here. Suffice to say that we have complete confidence in the ability of our present team of editors to continue producing the kind of a magazine that our readers have been accustomed to receiving—a magazine that reflects throughout its editorial pages a close and understanding awareness of important developments in its field and the technical and journalistic competence to report those developments.

That COMBUSTION has been that kind of a magazine has been made evident to us by the gratifying volume of letters we receive each year from readers here and abroad expressing both their interest and satisfaction. It has also been evidenced in the numerous references to COMBUSTION articles in foreign technical publications and in the bibliographies of authoritative engineering books.

For all of this we are grateful, and this anniversary issue seems to be a particularly appropriate time and place to convey our sincere thanks.

Charles McDonough

Vice-Pres., Combustion Publishing Co., Inc.

Gleanings From A Quarter Century of COMBUSTION

On the cover of this issue the initial aims and objectives of this magazine are repeated. They serve as an excellent means of judging the effectiveness of the publication over the years of its life. Unfortunately the fullness of the magazine's coverage or the many individual highly significant contributions to the power field that have appeared in its pages do not lend themselves to capsule treatment. The following diary-like presentation attempts to convey the editorial standards the magazine has sought to maintain throughout its existence and at the same time salute the efforts of the men who made the magazine—the authors and contributors.

Outstanding among these authors for the lasting value of their contributions were:

Henry Kreisinger, director of research, Combustion Engineering Co., and his successor, **B. J. Cross,** whose early reports on pulverized fuel firing and combustion theories became fundamental reference material;

David Brownlie, London, England, who, from the magazine's inception and for a long span of years thereafter, supplied the magazine with the latest designs and research developments taking place on the European continent such as the supercritical pressure boilers of current interest here in America;

L. T. Parker, prominent Cincinnati attorney, who has interpreted plant and contract law over a span of years to the power field;

J. G. Mingle, now deceased, former air pollution control director of Indianapolis, who presented in the early '30's chimney design studies that removed much of the rule of thumb procedure of that day;

A. L. Nicolai and **W. S. Patterson,** Combustion Engineering Co., who furnished a series of articles on combustion calculations that are still applicable;

W. L. De Baufre, technical research dept., International Combustion Engineering Corp., whose writings on the fundamentals of thermodynamics were classics;

Sabin Crocker, then of Detroit Edison Co., who ran through 1935–1936 an 8-part item-by-item design discussion of the modernizing of the Conners Creek Power Plant that proved to be a reference digest of power plant design techniques;

H. E. Macomber, Detroit Edison Co., who followed up in 1943–1944 with a similar design digest of the modernization of the Marysville Power Plant;

R. C. Corey, now of the Bureau of Mines, who contributed heavily with research information on furnace performance factors, notably corrosion, as well as studies on fuels and firing behavior.

E. M. Partridge, chief chemist, Paige & Jones, whose clear and understandable descriptions of the functioning of zeolites or base exchange types of chemicals, plus the fundamentals of water softeners back in 1930, prepared the magazine's readers for the rapid changes then getting underway in water treatment techniques.

Otto de Lorenzi, Combustion Engineering, and **H. G. Meissner,** Combustion Engineering, who, over the years, have supplied highly informative articles on fuel burning, especially waste fuels, such as bagasse, bark and other wood wastes.

Throughout the years the magazine has endeavored to attain its objective of reporting on all matters "concerning present-day practice, new developments and future trends in the fields of fuel burning and steam generation" by comprehensively selecting all pertinent engineering and technical society papers plus actively seeking specially written articles by leaders in the power generation field. These gleanings, grouped under subject headings for convenience sake, reflect to some extent the efforts put forth over the years:

Boilers and Auxiliaries:

July 1929—On the great word war then waging between the advocates of bare as against covered furnace walls, "The conclusions to be reached are now fairly evident: (1) There is every reason in favor of full-cooled furnaces. (2) The bare tube screen has the advantage on cost and effect upon the boiler. (3) Smoking will depend upon the burners and operation; and only slightly upon impingement. (4) The short flame turbulent burner is generally more advantageous with all types of walls. (5) Covering is only desirable on screen surface in the ash-pit to protect tubes from abrasion. (6) Slag type furnaces would be better without any cooling if we find a suitable refractory bottom. (7) If cooling surface is employed in the furnace it should be bare so as to earn as big a return as possible."—**R. J. S. Piggott,** consulting engineer, Stevens & Wood, Inc., *Heat Absorbing Surfaces in Modern Boiler Furnaces.*

Nov.-Dec. 1934—The need for a reasonably flat final steam temperature curve over a wide range of loads was being widely studied. "Here is an article in two parts that traces the history and development of superheaters and then advances a new design—the compensating superheater—which is described as a design where all of the gas at all loads flows in two paths over materially unequal surfaces. The gas is caused to flow so that a large percentage passes over the larger superheater surface at low load, the percentage becoming equalized at or near the maximum load"—**E. V. Rieder,** Detroit Edison Co. and **C. W. Gordon,** Superheater Co., *Regulation of Steam Temperature by Controlled Gas Flow, Parts I and II.*

June 1940—Forced circulation boilers in England—"A table of 25 forced circulation boilers installed or on order in Great Britain shows 15 to be LaMont designs, 5 Sulzer, 4 Loeffler and one Velox. The author sums up the following advantages: (1) an ability to use smaller tubes, hence reduced wall thickness for high pressures; (2) reduction in number, or in some cases, elimination of

drums; (3) freedom to distribute the heating surface to the greatest advantage with respect to heat transfer; (4) ability to obtain large evaporation in a given space; (5) reduction in weight per units of output and a claimed absence of troubles from scale formation inside the tubes. Offsetting these advantages is the inclusion of pumping equipment and in some cases elaborate controls"—*The Thomas Hawksley Lecture* before the Institution of Mechanical Engineers, London, by *Sir Leonard Pearce.*

Oct. 1944—High pressure steam cycles were imposing heavy burdens on feed pumps—"A review of mechanical properties of materials suitable for boiler feed pump construction, especially for high pressure service. The phenomenon of erosion-corrosion and its prevention is discussed."—L. J. Dawson, Cameron Pump Div., Ingersoll Rand Co., *Practical Aspects of Boiler Feed Pump Materials Selection.*

Dec. 1948—With over two million kilowatts of reheat capacity then on order or under construction the reheat boiler was a topic of major interest. "These papers clarify both the economic considerations and the operating problems involved with reheat boilers. They are in general agreement that although reheat boilers cost more when considered on a steam output basis such increases are largely offset by the reduced sizes of steam generating unit, feed pump equipment and condensing equipment resulting from the lower water rate of the turbine; so that on the basis of kilowatt output there is little difference in total initial cost. Moreover, an improvement in station heat rate of four to eight per cent, and in some cases more, results." **Martin Frisch,** Foster Wheeler Corp., *Steam-Generating Equipment for Resuperheating Cycles*; **W. R. Rowand,** Babcock & Wilcox Co., *High Pressure Boilers with Reheaters*; **W. S. Patterson,** Combustion Engineering Co., *Modern Reheat Boilers*—ASME Annual Meeting.

Nov. 1953—Supercritical pressure steam power plants now seem about ready for application in the United States with a promise of improved cycle efficiencies. "Only units of large capability can be economically justified for operation at or above the critical pressure with turbine unit sizes in the range of 150,000 kw or larger. Further, additional experimental data is needed upon which to base steam tables in the regions beyond critical pressure. Thermodynamic analyses reported were on the basis of extrapolations from the Keenan and Keyes steam tables."—**Professor Jerome Bartels,** Polytechnic Institute of Brooklyn, **C. D. Wilson,** turbine design engineer, Allis-Chalmers Mfg. Co., *Supercritical Pressure Plants.*

Water Treatment:

1929–1930—Generation of ever greater quantities of steam from each unit of heating surface was the expressed aim of boiler designers during these years. Evaporation rates had jumped from a usual 7 to 8 lbs of water per sq ft of heating surface in 1924–1925 to as high as 25 lb per sq ft. In water walls the rate exceeded 25 lb and went as high as 50 lb per sq ft. The problem was gaining recognition as an intricate physical-chemical one so that theoretical discussions were quite common.

May 1930—"A follow-up article of previous reports by **A. A. Markson,** mechanical engineer, and **A. R. Mumford,** New York Steam Corp., suggests four more points of importance in water conditioning: (1) A minimum alkalinity, corresponding to a pH of 10–11, is as important as establishing a definite maximum. (2) Keep boiler water free of saponifiable matter and organic contamination. (3) Hold collective total of dissolved and suspended solids in boiler water as low as possible. (4) Since carbon dioxide is undesired and unessential, maximum elimination of its source—bicarbonates and carbonates—in entering feedwater is essential."—**R. E. Hall,** Hall Labs., *Development of High Pressure System for Water Conditioning.*

Aug. 1929—"A very interesting development, also in British power practice, which has not yet made much progress in the United States is the treatment of the cooling water with a measured trace of chlorine gas so as to give complete sterilization and prevent the growth of organic deposits on condenser tubes."—**David Brownlie,** London, England, *Power Station Practice in Great Britain.*

July 1934—"Results obtained in practical condenser operation have demonstrated the ultimate value of the chlorination process from the standpoint of a profitable method of controlling condenser tube fouling where slime and algae growths are the fouling substances. When this method is properly applied and controlled, there is indication that the results obtained will be most satisfactory, both in costs and advantages in comparison with former methods of condenser slime control."—**Don J. Nemeth,** results engr., Detroit Edison Co., *Chlorination of Condenser Water.*

June 1935—"An attempt to impartially judge the divergent views of authorities on siliceous scale prevention. Hardness is no index, pH ought to be about 11.0, and, most important, evaporation is not a means of elimination since the author notes that siliceous materials carry over with the steam."—**R. E. Summers,** assistant professor, mechanical engineering, Oregon State College, *Anomalies of Siliceous Material in Water Chemistry.*

June–Sept. 1939—A series of articles prompted by the interest in recirculation of boiler salines covered the various ways of introducing the recirculated water at the hotwell pump suction, through softeners, etc. "Recirculation of from 1–2 per cent of boiler water to correct the hydrogen ion concentration of the feedwater for protection of economizers, feedwater pumps and piping. This scheme is not universally applicable but one good application is where hot process softeners of the lime soda or phosphate type are used."—**S. M. Sperry,** Utility Management Corp., **John J. Maguire,** W. H. & L. D. Betz, **W. J. Tomlinson,** Wood Industries, Supply Co., Ltd.

May 1940—The industrial power plant was openly interested in higher pressure boilers and power cycles. Water treatment was one serious consideration—"Boiler feedwater is still a major problem in high pressure industrial plant operation. Return lines from process should be closely watched and equipped with conductivity meters and alarms. Further the higher first cost and lower efficiency measured by the net kilowatt-hours produced will force the evaporator cycle to give way to further progress in water treatment within five years."—**H. D. Harkins,** E. I. du Pont de Nemours, discussing *Higher Pressures in Industrial Plants* by **W. F. Ryan,** mechanical engr., Stone & Webster Engrg. Corp.

June 1945—"Tests indicate silica leaves the boiler as silicic acid and later crystallizes on the lower blades of

the turbine. If silica is below 0.1 ppm in the steam no trouble develops. But to prevent deposits silica should be kept below 5 ppm in the boiler water and silica scrubbed out of the steam by a pure grade water."—**F. G. Straub, H. A. Grabowski,** Univ. of Illinois, *Silica Deposition in Steam Turbines.*

Dec. 1944—For several years the practice of demineralization or the external removal of contaminants had been gaining in appeal. "With these 1400-lb units essentially all the feedwater is chemically treated external to the boilers, phosphoric acid and caustic soda being fed to the hot process softener. Resinous ion-exchange material was in the development stage at the time of these boiler installations (1942) and was not satisfactory for high temperature use. The writers believe these installations are the only ones of their type operating at 1400 psi so treated."—**L. F. Wirth,** Dow Chemical Company, and **C. E. Joos,** Cochrane Corp., *Feedwater Treatment for High-Pressure Boilers at Dow Chemical Co.*

Nov. 1949—On demineralization and ion-exchange water-treatment operating experiences, a highlight of the Tenth Annual Water Conference of the Engineers Society of Western Penna., Oct. 1949. "At the Midland plant of Dow Chemical Co. the header system is applied with an extensive central control system that is almost completely automatic. Water costs, including chemicals, wash water, and the cost of water being processed are on the order of 27 cents per thousand gallons with improvements in operation now planned that will reduce these costs."—**L. F. Wirth,** power div., Dow Chemical Co.

"Present evidence with operation of resin zeolites indicates these materials have long life when installed under proper conditions. Phenolic base materials withstand high and low pH, high temperature, attack by algae, fouling with growths, ion and calcium deposits and attrition due to repeated backwashing, but they are affected by free residual chlorine concentrations in excess of 0.8 ppm."—**V. J. Calise,** Graver Water Conditioning Co., *Experiences with Resin Zeolites in the Hydrogen Cycle.*

Nov. 1953—Chemical cleaning of metal surfaces, particularly those of boilers, heat exchangers and condensers by acids has become an accepted operating procedure especially saving of labor costs. "Although hydrochloric acid is the principal solvent currently used for chemical cleaning, new materials and techniques are rapidly replacing it for some applications. Attempts are being made to develop new scale removing chemicals which will eliminate the use of mineral acids altogether. Realization of such developments would solve many current problems including acid corrosion, disposal of spent solvents and after-rusting difficulties."—**P. H. Cardwell,** Dowell Inc., *Chemical Cleaning Advances.*

April 1954—"The undesirable properties of sulfite such as its decomposition to sulfide and its tendency to seep around hand hole gaskets, valve stems and pump glands resulted in corrosion and scale formation so that maintenance ran heavy, particularly for 900 psig boilers. Several chemicals were tried and hydrazine seemed most promising. It seems to have definite advantages as an oxygen scavenger in high-pressure boiler service, but proved somewhat difficult to control within desirable limits."—**E. C. Fiss,** chief chemical engineer, Duke Power Co. *Experience in the Use of Hydrazine for Boilers.*

Fuels and Firing:

Nov. 1929—The West Coast was beginning to expand and looking for accessible fuel supplies. "An interesting story of tapping nature's reservoirs for the commercial needs of society. Here is a fuel that provides its own motive power for transportation over the several hundred miles between wells and cities."—**C. W. Geiger,** San Francisco, *A 282 Mile Pipe Line for Natural Gas.*

1934—The period from the early thirties through the depression was characterized by a quantity of excellent articles and papers covering all the phases of fuel burning and especially so for pulverized coal, viz., the Kreisinger, Nicolai and Patterson series. Still others of note on less frequently reported matters were the articles, *Tempering Coal and Its Effect on Combustion*—**R. A. Sherman,** Battelle Memorial Institute, **J. R. Blanchard,** cooperative research fellow, Battelle Memorial Institute and Ohio State Univ., **D. J. Demorest,** professor of metallurgy, Ohio State Univ.—Dec. 1934—and *Lignite Burned on Traveling Grates at University of Texas*—**Carl J. Eckhardt,** Jr., Univ. of Texas and **W. H. Wood,** Combustion Engineering Co.

May 1940—An early study of limited interest at the time of its presentation but of later national value. "A review of the principal differences in operating characteristics that show up in changing from pulverized coal to natural gas or vice versa. With boilers operating with 100 deg superheat or less, no problems are apt to show up. But with 300 deg of superheat or more, control of final steam temperature may be difficult. Simultaneous use of the fuels could render automatic combustion controls valueless. CO_2 percentages that are correct for all coal fail with introduction of gas mixtures and are incorrect with all gas. The answer seems to be a control based on the measurement of excess oxygen in the flue gas."—**H. A. Kleinman,** Peoples Power Co., *Intermittent Burning of Gas and Pulverized Coal.*

Oct. 1944—"A review of what has happened abroad, typical yields to be expected from various U. S. coals, as established by preliminary research, and the program planned by the Bureau of Mines under the recently passed Synthetic Liquid Fuels Act."—**A. C. Fieldner, H. H. Storch, L. L. Hirst,** U. S. Bureau of Mines, *Hydrogenation and Liquefaction of Coal and Lignite.*

Dec. 1949—"A laboratory setup and procedure for investigating the effect of pressure on combustion of pulverized coal produced these results. The degree of completeness of combustion, even at temperature levels giving uniform ignition, increased strongly with increasing temperature, increased moderately with partial pressure of oxygen and was strongly depressed by increasing total pressure."—**T. T. Omori,** California Institute of Technology and **A. A. Orning,** Carnegie Institute of Technology, *Effect of Pressure on Combustion of Coal.*

March 1954—"Here is some of the development work behind the attempt of the Texas Power & Light Co., and the Aluminum Co. of America to use a char produced from low temperature carbonization of lignite as a direct fuel for power generation and, in the process, get a yield of marketable tar that will make the project pay."—**V. F. Parry,** U. S. Bureau of Mines, *Low Temperature Carbonization of Coal and Lignite for Industrial Uses.*

Steam and Gas Turbines:

Jan. 1935—"It appears as though the superposition of high pressure, high temperature equipment exhausting into older low pressure equipment will be used extensively in the near future since it increases capacity of old stations, and gives a measurable increase in net overall thermal efficiency. Another very late proposal was to use turbine and boiler as a unit with the turbine output controlled by variation of boiler pressure. It is significant that at least one manufacturer expresses willingness to construct a 200,000 kw turbine to operate with an initial steam pressure of 1200 psi, and 1000 F, tandem type, no reheat."—**C. F. Hirshfeld,** chief of research, Detroit Edison Co., *Progress in Steam Power.*

Jan. 1940—"A committee of the Verein Deutscher Ingenieure working with the German Standards Commission from 1936 recommended standard steam conditions involving 15 pressures and an incremental series of sixteen steam temperatures. This report brings this standardization up to date to involve boilers, fittings, economizers, auxiliaries, and piping as well as turbine generators. Steam conditions have been set at four pressures—569, 910, 1138, and 1778 psi—and steam temperatures at 842 F and 932 F. Twelve capacities have been fixed and provisions made for standardized types. Rules have been promulgated for manufacturers on de livery and relations between purchasers."—News report on *Further Power Plant Standardization in Germany.*

Mar. 1940—"Escher Wyss has developed a combustion turbine operating on a new principle. It involves a closed circuit in which the combustion products do not flow through a turbine but instead heat air as a working medium which passes through a separate circuit."—*European news report.*

May 1940—"A discussion of the development work of Brown Boveri in connection with the Holtzwarth gas-turbine cycle since 1909, particularly with reference to supercharging. Now with an accurate knowledge of thermodynamics of gas combustion, materials to withstand combustion gas at 1000 to 1100 F, and an air compressor with sufficiently high adiabatic efficiency to convert the former power deficiency into surpluses the gas turbine has come into its own. Present thermal efficiencies limited by available materials are not high enough for primary power generation but the gas turbine with its rapid starting has possibilities for standby and peak-load service."—**Paul R. Sidler,** Brown-Boveri Co., *The Combustion Gas Turbine.*

Nov. 1944—"The author covers probable trends and comments at length on the proposed ASME-AIEE Standards for ratings and steam conditions for steam turbine generators from 10,000 kw to 60,000 kw."—**C. B. Campbell,** Westinghouse Electric & Mfg. Co., *Progress in Steam Engineering.*

May 1950—"A follow-up of an earlier paper in June 1947 adopts the same principle of a quick-start procedure to admit steam at a temperature equal to or higher than the metal temperature of the heavy section of the machine. This paper points out a fallacy in the belief of some operators that little or no metal stress develops in the turbine when it is started immediately after an accidental shutdown. Even after a few minutes shutdown the turbine temperature may be several degrees hotter than the entering steam on restarting. The turbine spindle, with its higher rate of heat transfer, cools off faster than the turbine shell and a possible forward axial rub may result."—**J. C. Falkner, D. W. Napier, C. W. Kellstedt,** Consolidated Edison Co. of N. Y., *Quick Starts on Large Turbines and Boilers.*

Sept. 1953—"An analytical study to determine the feasibility of using exhaust gas from a gas turbine to support combustion in an existing steam generator and the effect of this arrangement on both steam generator performance and the combined heat rate."—**J. F. Lee,** associate professor, mechanical engineering, North Carolina State College, *The Gas Turbine as a Combustion Topping Unit.*

Nuclear Energy:

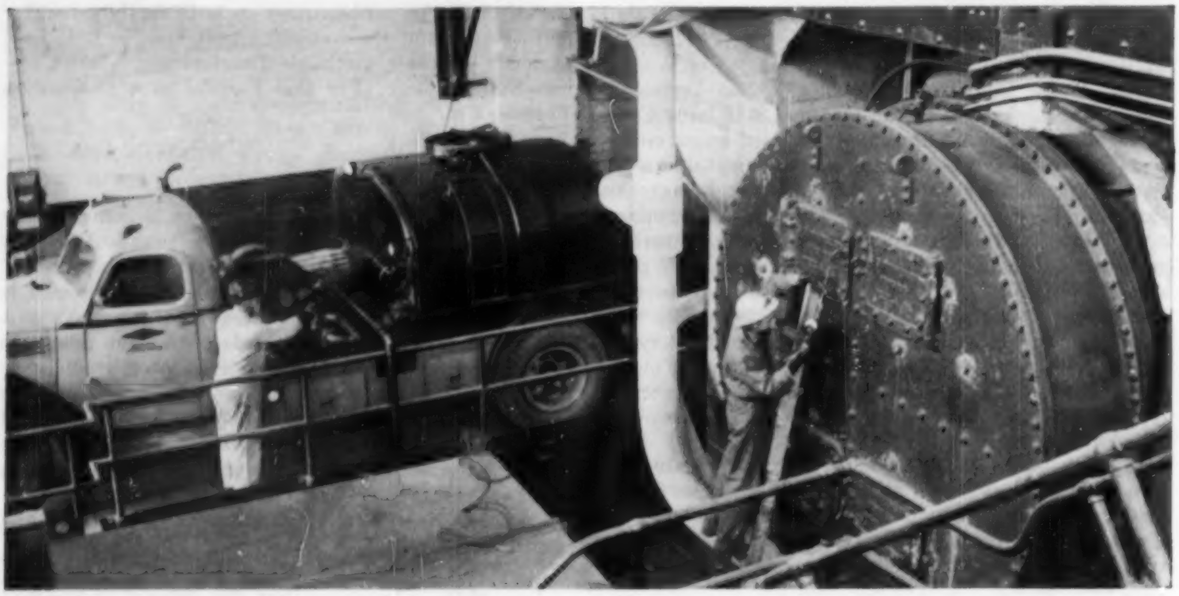
Nov. 1947—"There are at least four elements to the problem of making atomic power a practical reality. One is to get energy in a usable form, which probably means in the form of high-temperature heat. Second, is to have a reasonable rate of generation of power per unit of nuclear fuel invested. Third, is to have adequate stocks of such fuel to activate a sizable atomic power industry. Fourth, is to prevent wastage or loss of this precious fuel in the complex business of handling it. All in all, the author concludes that at least eight to ten years will lapse before a useful and practical demonstration plant is operating."—**David E. Lillienthal,** chairman, U. S. Atomic Energy Commission, *Atomic Energy and American Industry.*

Dec. 1949—"Assuming that the problem of breeding will have been successfully developed, one pound of uranium will do the work of 1500 tons of 13,000 Btu coal. While the fuel cost, as such, will be cheap the processing of the fuel will involve elaborate and relatively expensive chemical operations. Estimates of capital costs have ranged from $140 to as high as $1000 per kilowatt upon which depreciation rates will be higher than normal because of the more rapid obsolescence in a new technology."—**Phillip A. Sporn,** president, American Gas & Electric Service Corp., *Atomic Energy Power Prospects.*

June 1954—The first six months of 1954 saw so many proposals and discussions on the development of atomic energy for peaceful purposes that Dr. Lawrence R. Hafstad, director of the AEC reactor development division, declared we were now ushering in the "second generation" of power reactor development. The following article reflects this development. "No one has ever built a power reactor like this before. The slight enrichment, the long core life span, the deliberate intent to burn plutonium after it is generated through reactor operation, the use of ordinary water in conjunction with the other features, and additional matters which I am not at liberty to disclose—each of these objectives considered separately, is without precedent, at least in the free world. Considered in the aggregate, they mean that we are struggling to take a long stride into the unknown."—**C. H. Weaver,** Westinghouse Electric Corp., *Basic Design of First Central Station Nuclear Power Plant.*

CHEMICAL CLEANING SAVED 400 TONS OF COAL PER YEAR

Fly ash, soot and carbonate deposits removed from condenser by Dowell; vacuum increased



Fly ash and carbonate deposits on the water side of an 800-KW turbo surface condenser had reduced vacuum from a normal 28" to 24". The temperature of the water leaving the condenser had dropped from 95°F. to 85°F.

These deposits were removed by Dowell Service with specially prepared liquid solvents. Result: the condenser was restored to its normal operating efficiency. The steam requirement was reduced by 2.5 pounds per kilowatt hour. On the basis of 8,000 hours of yearly operation, the plant engineer calculated a saving of at least 400 tons of coal per year.

Dowell chemical cleaning methods can be used on hundreds of different kinds of industrial equipment. Engineers especially trained for this kind of work do the job for you. They apply solvents according to the technique demanded by the job: filling, spraying, jetting, cascading or vaporizing. Dowell liquid solvents can go wherever steam or water will flow, reaching places inaccessible to other cleaning methods. Scaffolding is unnecessary. Dismantling and downtime are kept to a minimum.

A call for Dowell Service will bring experienced personnel to your plant within a few hours with all necessary chemicals, pump trucks and control equipment. For complete information and estimates on the cleaning of your equipment, contact the nearest Dowell office, or write directly to Tulsa, Dept. G-25.

DOWELL SERVICE

Over 100 Offices to Serve You with Chemical Cleaning for:

Boilers • Condensers • Heat Exchangers • Cooling Systems
Pipe Lines • Piping Systems • Gas Washers • Process Towers
Process Equipment • Evaporators • Filter Beds • Tanks

Chemical Services for Oil, Gas and Water Wells

DOWELL INCORPORATED • TULSA 1, OKLAHOMA

DOWELL

A Service Subsidiary of
THE DOW CHEMICAL COMPANY

The Application and Development of the Turbo Steam Separator

In the advancing art and science of boiler design, considerable developmental effort has been expended upon improving methods of steam separation. The primary reasons for continuing interest in this process are (1) the need for steam of maximum purity because of its effect upon turbine performance, (2) the desirability of separation with minimum effect upon boiler circulation, and (3) the desire to achieve steam separation within tolerable space requirements.

By T. RAVESE
Combustion Engineering, Inc.

NUMEROUS laboratory and field tests were made of various designs of steam drum internals before the unit described in this article was adapted as a standard for present boilers. Fig. 1 shows a section through the turbo steam separator. The unit is mounted vertically on a supporting flange which is set on a companion flange welded to the steam drum panel. The steam-water mixture enters the turbo separator at the bottom of the primary unit. As this mixture flows upward, the fixed spinner vanes throw the water to the outer edge of the tube thus forcing the steam toward the inside of the tube. Just above the spinner is a steam collector nozzle with a skim-off lip which captures the layer of water flowing along the outer edge of the primary tube and returns it to the drum through the annulus surrounding the inner tube. This is the first stage of steam-water separation.

Steam then passes through the steam collector nozzle into the secondary separator for the next cleaning stage. The second stage of the separator consists of the two opposed banks of closely spaced thin corrugated plates or sheets which direct the steam horizontally in a tortuous path and force any remaining water against the corrugated plates. Since the velocity is relatively low, this water cannot again be picked from the wetted surface and therefore runs down the corrugated plates and off the second-stage lips away from the two steam outlets. The steam outlets can discharge in any desired direction since the secondary separator can be positioned at any angle on the primary tube. The steam outlets can discharge along the length of the drum, across the drum or in intermediate positions. This makes it possible to position the secondary-separator steam outlets to the best advantage.

In the case of natural circulation boilers where consideration must be given to the pressure loss through the internals the secondary-separator steam outlets discharge across the drum so that the maximum number of units can be installed. On controlled-circulation boilers fewer turbo steam separator units are required, and the secondary steam outlets discharge lengthwise in the drum.

Installation in Natural-Circulation Boiler

A typical section through a steam drum with turbo steam separators installed in a natural-circulation boiler is shown in Fig. 2. The steam-water mixture discharges through nozzles into the drum and is collected in a compartment formed by internal baffles of welded-panel watertight construction. Two rows of separators are used; one row is mounted directly on this compartment and the second row is mounted on tube elbows which are connected to the side of the same compartment. Since the friction loss in the connecting tube is small with respect to the loss through the separator, good flow distribution through the units is obtained. Screen dryers are positioned directly below the steam outlet nozzles in the drum. These dryers provide the third steam cleaning stage as well as a deterrent for steam carryover during abnormal conditions when steam drum water level may be above the range of the gage glass. Chemical feed and continuous blowdown locations have been selected to best advantage to insure minimum blowdown and maximum mixing of chemical with boiler water.

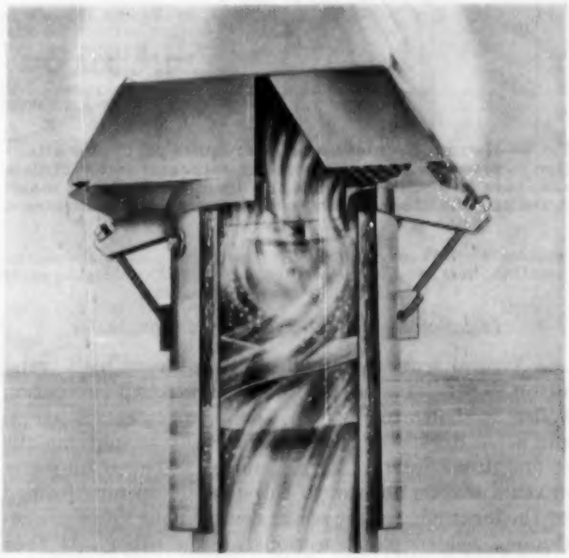


Fig. 1—Sectional view through a typical turbo separator illustrates the major paths through which the separator puts the steam-water mixture to deliver a steam of maximum purity to the drum outlet

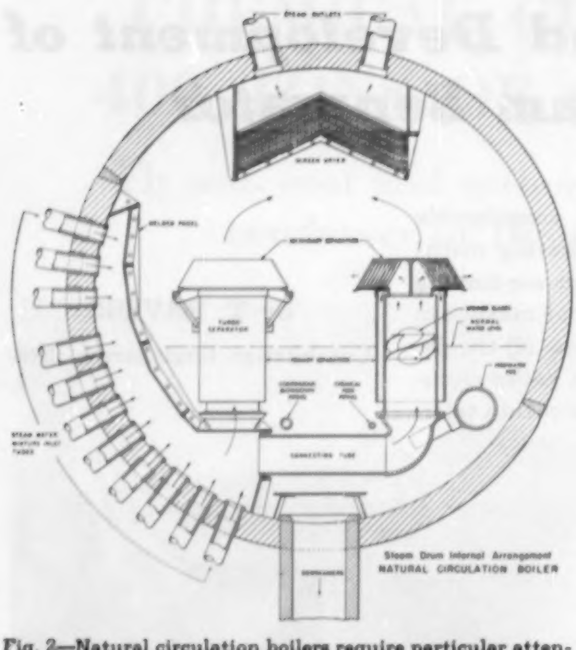


Fig. 2—Natural circulation boilers require particular attention to pressure losses so secondary-separator steam outlets are made to discharge across the drums and allow a maximum number of separators to work toward optimum steam conditions

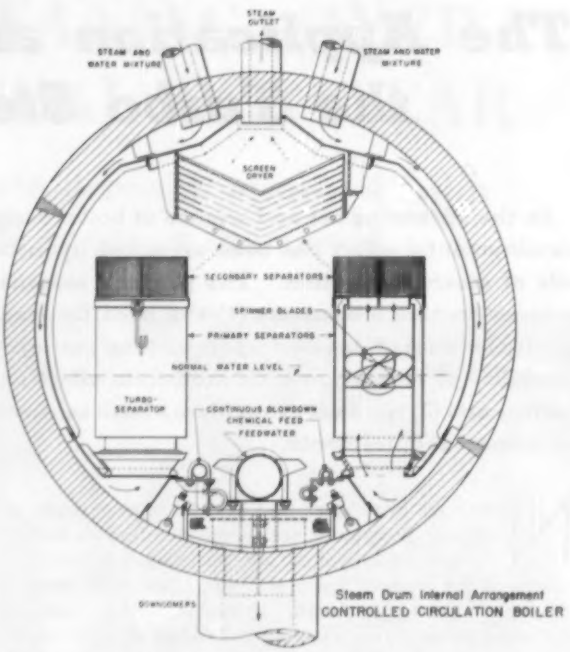


Fig. 3—Controlled circulation designs permit employing a pressure drop across the separator to advantage and hence fewer separator units are needed and they can discharge steam lengthwise in the drum

Installation in Controlled-Circulation Boiler

A typical section through a steam drum with turbo steam separators installed in a controlled-circulation boiler[1] is shown in Fig. 3. The arrangement of panels and separators is symmetrical, thereby simplifying the steam drum internal arrangement. The steam-water mixture travels downward through the opening formed by the inner edge of the steam drum on one side and continuous welded panel sections on the other. It then flows upward with steam outlets from the secondary separators discharging along the length of the drum. The screen dryers are set directly above the separators as is the case for natural circulation boilers. Locations are shown for the continuous blowdown and chemical feed lines. The feed line is set at the bottom of the drum with perforations directly over the downcomers. This minimizes steam condensation in the drum and assures maximum net positive suction head for the circulating pumps.

Method of Installation

All the steam drum welded panels are installed in the shops and pressure tested for tightness so that the only field work consists of installing the turbo separators. The bolting arrangements of the primary and secondary units make the installation task a simple one. It is possible to install or remove all separators for a large boiler in about a half day. This is a highly desirable consideration for expediting work during maintenance periods. Inspection plugs are provided in the panels so that the drum welds can be inspected.

[1] This was described briefly by Mr. W. H. Armacost at the 1953 ASME Annual Meeting in a paper entitled "The Controlled-Circulation Boiler." See COMBUSTION, 25, No. 7, 38–44, Jan. 1954.

Drum Metal Temperature on Startup

This type of drum internal installation in controlled circulation boilers insures uniform shell temperatures because of the positive circulation supplied by the pump. The boiler can be brought up to normal operating pressure in much less time than a similar natural circulation boiler without incurring temperature stresses due to uneven heating of the shell.

As an example, tests were made on one of the recently installed controlled circulation boilers in which the shell temperature rise averaged 220 deg F per hr. These data are shown plotted in the accompanying curves of Fig. 4. Maximum temperature variations in the shell are less than 70 deg F. Additional minor changes in the design of drum baffles have been made to reduce even further the small differences in shell temperatures.

Development

In 1942 this company designed and built a controlled circulation boiler for the Bureau of Ships and installed it in the Boiler and Turbine Laboratory of the Philadelphia Naval shipyard. In keeping with Naval requirements and also to minimize use of critical materials during World War II, the unit was designed for extreme compactness, thereby saving considerable weight and material in the pressure parts. Since this particular boiler was intended for use at the laboratory, a smaller steam drum than was dictated by the drum internal knowledge at that time was installed, and further development work was anticipated.

Shortly after the start of an intensive steam purity test program it became evident that no modification of existing steam drum internals would meet the rigid Navy

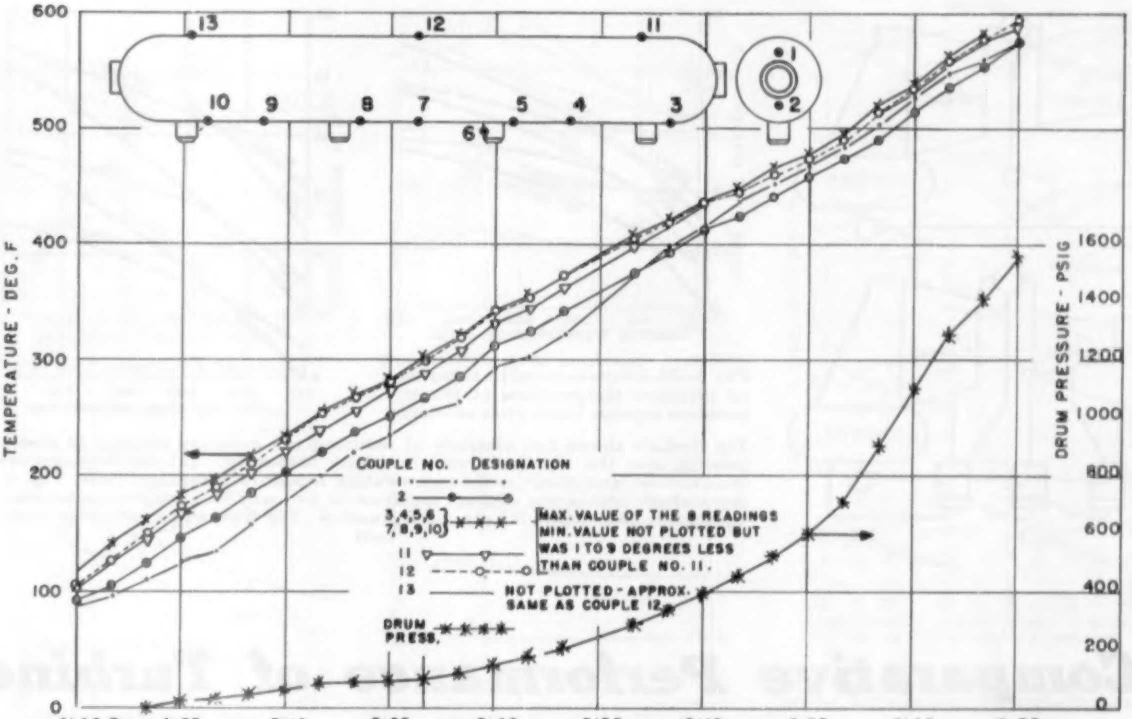


Fig. 4—Arrangement of drum internals in Fig. 3, coupled with the positive circulation supplied by the pump in controlled circulation boilers, insures uniform drum shell temperatures as plotted above, which makes faster start-up times possible without incurring stresses from temperature differences in drum metal

specifications of steam dryness. A program of development of drum internals was begun shortly thereafter. In this design advantage could be taken of the available head in the circulating pumps for the controlled-circulation boilers.

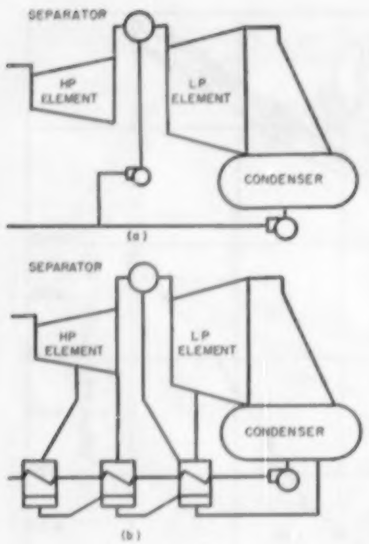
Following initial intensive investigation the separator designs were limited to those employing the fundamental principle of centrifugal separation. Numerous types of drum internals were tested before the separator now in commercial use was developed. The present unit was adopted only after rigid tests showed that it was capable of surpassing performance guarantees. Tests at the laboratory showed that the solid carryover in the steam was less than 0.5 ppm when the boiler water concentration was in excess of 1100 ppm and drum water level varied three in. from normal.

In 1950 installations of turbo steam separators were made in two stationary natural circulation boilers, one operating at 1400 psig. Later in the same year these internals were installed in the Montaup controlled-circulation boiler where replacement of existing internals was necessary because of acid corrosion of the internals. Tests were conducted with two circulating pumps, which are normally in service, and with three circulating pumps at full load on the boiler. Steam purity results were not adversely affected by the additional water which was circulated by the third pump.

In every case the turbo steam separators proved superior to the internals which had been replaced. This was because they permitted (1) higher drum water level operation, (2) buildup of boiler water concentration to higher values, (3) generation of steam with less solid carryover and (4) eliminated the necessity for the front steam-separating drum in natural-circulation boilers. The Montaup tests showed that the steam dry drum is also unnecessary, and this drum is omitted in current designs of controlled-circulation boilers. Also, it has not been necessary to wash the topping turbine at Montaup since the installation of the turbo separators, whereas previously it was necessary to do this on an intermittent basis. Preliminary tests on recently installed controlled-circulation boilers show that the total dissolved solids concentration in the saturated steam is less than 0.1 ppm with normal boiler water concentration. In the newer controlled-circulation boilers, which have been in operation nearly two years, there is similar indication that turbine washing is not necessary.

Conclusion

Present designs of turbo steam separators have been successfully used in boilers operating from 700 to 2600 psig and having capacities ranging from 400,000 to 1,100,000 lb of steam per hour. Designs are being projected for boilers of smaller capacity as well as for units having a steam output of 1,700,000 lb per hr and higher. The internals now in use have permitted operation of boilers with more efficient steam separation in smaller diameter drums than previously required. They also permit greater steam release per foot of drum length. Field experience over a period of seven years indicates that the original objectives of the development program have been fulfilled. Further investigations are now in process to obtain higher steam release rates and even more efficient steam separation.



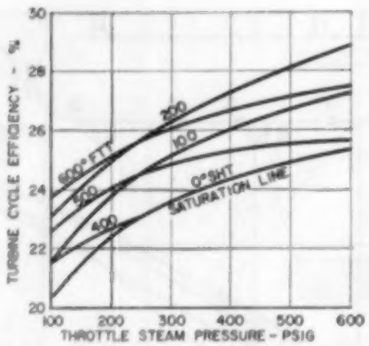


Fig. 2—Moisture removal by superheat at constant temperature at throttle pressure expense hurts cycle efficiency

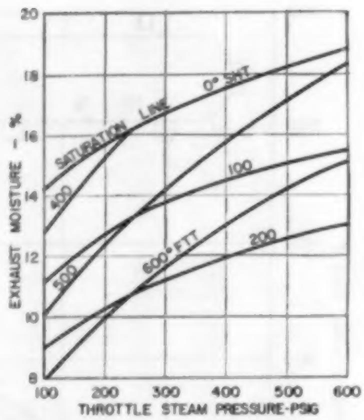


Fig. 1—Left shows two methods of reducing the moisture content in steam passing over the last few rows of turbine blades by: (a) non-regenerative moisture-separator cycle, (b) regenerative moisture separator cycle. Fig. 3, right above, shows the exhaust moisture in per cent for straight condensing-turbine-cycle at 1.5 in. Hg abs. back pressure. Fig. 2 shows performance, same unit.

Comparative Performance of Turbine Units in Saturated Steam Cycles*

This paper extends performance data for central-station turbine generators into the region of saturated steam where few or no data are available for large unit ratings of the order of 100 mw capability or greater. In the region of saturated steam some moisture reduction steps are needed and the various schemes are discussed as well as a brief review of turbine design considerations.

By N. A. BELDECOS and A. K. SMITH

Westinghouse Electric Corp.

In atomic power plants, the physical properties of some nuclear-reactor structural materials and coolant media impose serious limitations on the steam-generator-outlet temperature which results in turbine-throttle conditions radically different from present-day practice. At first glance, the utilization of saturated-steam turbine cycles appears as a complete reversal of the years of development which have extended operating conditions to supercritical pressures and temperatures. The substitution of a nuclear reactor as the heat source in a power plant introduces radical changes in the fuel and capital cost picture, and since the plant efficiency requires economic justification, it is not possible to exclude saturated-steam cycles from consideration.

This paper is intended for integration with other investigations which are being made to evaluate properly the application of atomic energy to central-station power generation. Though numerous performance data[1,2] are available to elevated temperatures, few data at reduced temperatures in the vicinity of saturated steam for large unit ratings are available. This paper supplements available steam-cycle performance data for large turbine-generator units in the region of saturated steam. Turbine-generator units of large capability offer the desirable features of low unit cost and high efficiency. A high percentage of units purchased for central-station application in recent years are rated at 100 mw or larger with a few units as large as 250 mw. For these reasons, this investigation has been restricted to units of 100 mw capability or greater.

Since the steam-turbine cycle performance is subject to many variables, the data presented is meant only to establish a performance level and trend which can be anticipated with present-day turbine practice. The turbine efficiencies used in arriving at the cycle efficiency have been derived from available information on units operating at elevated temperatures. These efficiencies have been extended for application in the region of saturated steam by the introduction of a moisture correction. The Appendix at the back of the article reviews the procedure followed in the determination of cycle performance. (See pp. 53-54)

* Presented before the Semi-Annual Meeting, the American Society of Mechanical Engineers, June 20–24, 1954, Pittsburgh, Penna.

1 "Thermal Performance of Modern Turbines," by Reese, H. R., and Carlson, J. R., *Mechanical Engineering*, Vol. 74, 1952, pp. 205–211.

2 "Performance Data 1260. Condensing Turbine Generator Units, 12,650 kw to 100,000 kw, Inclusive," AIEE-ASME Preferred Standard Rating Westinghouse Electric Corp., June 1951.

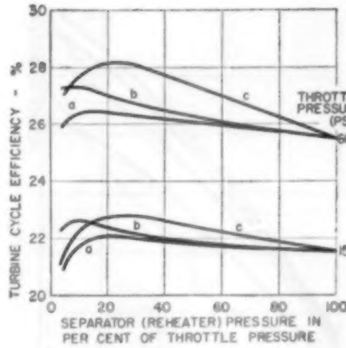


Fig. 4—Preheater vs. separator

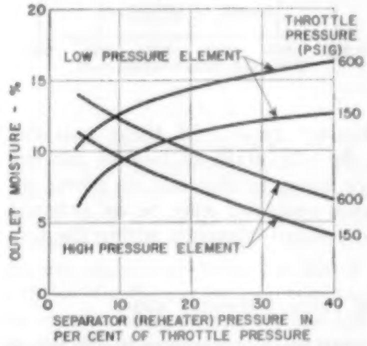


Fig. 5—Turbine element outlet moisture

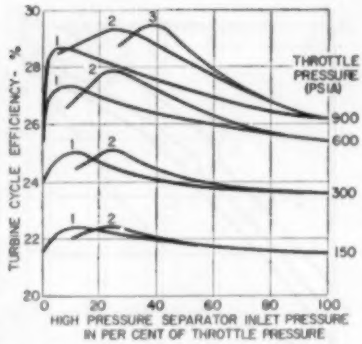


Fig. 6—Effect of separator location

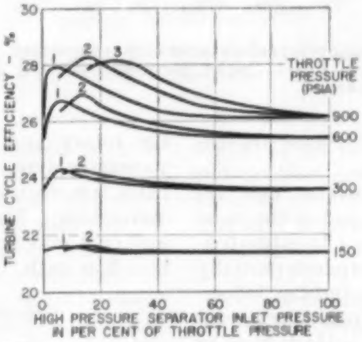


Fig. 7—Separators, 5% less moisture

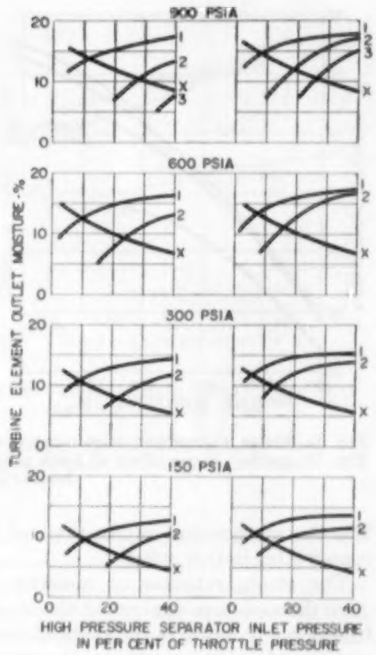


Fig. 8—Separator effect, 1% moisture outlet, left column; 5%, right column

The sections on turbine-design consideration and moisture reduction, below, have been included to introduce the reader to the problems arising from the use of saturated-steam cycles. This background information is desirable for a better understanding of the performance data which follow in later sections.

Turbine-Design Considerations

Before any thermodynamic investigation of the saturated-steam turbine cycle, let's review briefly the turbine features affected by the use of saturated steam.

Owing to the reduced throttle temperatures and pressures and available energy, both the mass and volumetric flow are correspondingly large, and dictate an increase in the turbine size. Turbine size is restricted by the available exhaust-blade flow area which in turn is established by mechanical strength considerations of the turbine blading. The limitations on the exhaust-annulus area result in an increase in the number of low-pressure ends and the multiple compounding of the turbine elements. Because of the larger exhaust-annulus area available in the 1800-rpm unit, its maximum capability is greater than that of the 3600-rpm unit. At the head end of the turbine, the large volumetric flow and resulting space limitations make the design of the control valves and partial admission stages difficult and may dictate their elimination, particularly in base load machine applications. For speeds and drum diameter comparable to present-day practice, fewer stages of turbine blading are required because of lower available energy.

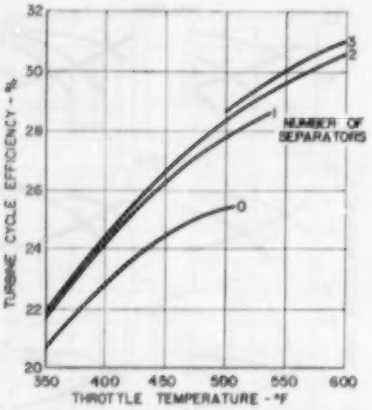
The large volumetric steam flow improves the internal dry-stage turbine efficiency, but this effect is more than offset by the moisture correction. Not only is moisture detrimental to efficiency, but it also dictates extensive maintenance which increases rapidly with increase of moisture and places severe limitations on the life of the turbine. The life expectancy of the last few rows of turbine blades is estimated at 10 years for 12 per cent moisture and 6 years for 15 per cent moisture. A high moisture content undoubtedly will dictate extensive stellited blade shielding and stainless-steel cylinder liners. The prevalence of excessive moisture requires some scheme for moisture reduction which may impose design restrictions on the turbine.

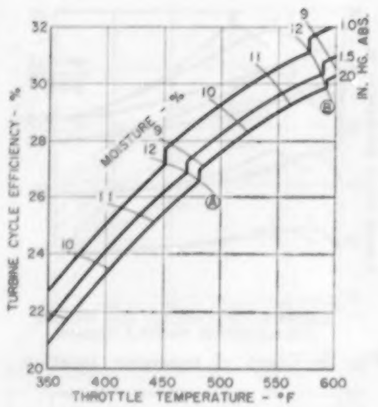
The consideration of exhaust losses is coupled closely with turbine size and efficiency. For a given annulus velocity, the percentage exhaust loss is greater in saturated-steam cycles than in cycles operating at elevated temperatures since the available heat drop is correspondingly smaller. Though the final selection of the low-pressure end is dependent upon an economic evaluation, it is evident that a more liberal exhaust-annulus area is justified in the saturated-steam cycle when it is compared to the superheat cycle on the basis of identical energy costs at the turbine throttle.

Moisture Reduction

With saturated steam, throttle steam pressures above 50 psig results in high end-point moisture especially when expansion occurs to back pressures meeting present central-station practice, so some method of moisture reduction must be affected. By using higher back pressures, or lower saturated throttle pressures, the steam-moisture content is reduced, but both of these schemes lower the cycle efficiency.

The addition of superheat at the turbine throttle is a desirable method for reduction of moisture, but only if there is a corresponding increase in the throttle pressure.





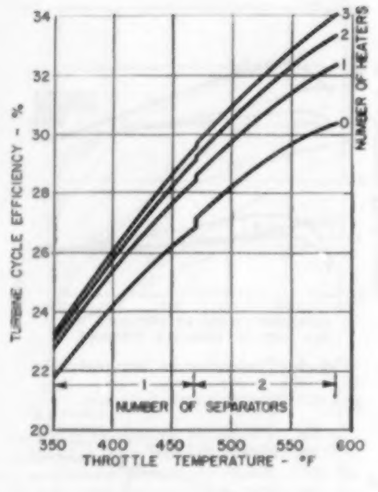


Fig. 9—Above, shows non-regenerative steam cycle performance with separators; Fig. 10, center, gives effect of back pressure; Fig. 11, right, pictures feedwater heater influence.

The thermodynamic implications of this scheme are discussed later in this article.

The steam reheater or moisture separator may reduce the moisture content of the steam, and at the same time serve to improve the cycle efficiency. In saturated-steam cycles using a reheater the steam expands partially through the high-pressure element of the turbine, following which heat is added to the steam from an external source before it returns to the turbine. Heat may be added to the steam in the following reheaters:

1. Combustion-fired reheater.
2. Primary coolant-circuit reheater.
3. Live-steam reheater.

Type (1) is similar to the conventional fired reheater. It is not a desirable arrangement because of the complexity of the additional heat source and its associated equipment. Heat exchangers of types (2) and (3) receive heat from the nuclear-reactor primary coolant—directly in one case, and indirectly through the boiler-generated steam in the other case. Type (2) makes possible the reheating of steam to the initial temperature but only at the cost of increased reactor shielding, piping and superheater surface. Type (3) reheater avoids any increase in the reactor shielding but it is only possible to reheat to the throttle temperature less the superheater terminal difference.

For the cycle using a moisture separator, the turbine arrangement, Fig. 1, is similar to that of the reheat cycle in that steam is removed from the turbine after partial expansion and piped to the separator for moisture removal before being returned to the turbine. The separator drains may be pumped directly into the feedwater or flashed to a low-pressure heater or condenser. There are many types of separator designs but all may be grouped into two general categories: (1) Baffle or screen type; (2) centrifugal type.

All separators employ a change in direction of the steam flow to accomplish the separation, but the difference lies in the force applied to bring it about. The one type uses a physical obstruction while the other takes advantage of centrifugal action. The centrifugal separator has the combined advantages of high efficiency, broad range of operation, low-pressure drop, and low cost. The centrifugal separator may be classified further into the rotary and stationary types. Of these two the stationary type has the advantage of lack of moving parts, low maintenance, minor erosion and no power requirements. The steam separator may be an external unit or it may be incorporated internally within the turbine-flow path.

Superheated Versus Saturated Steam

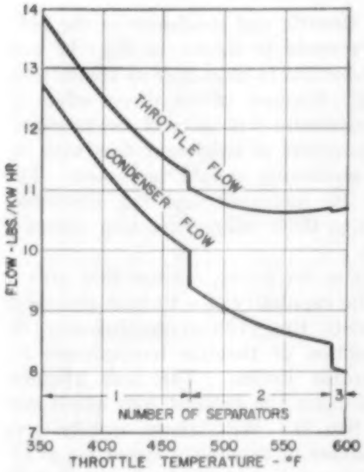
The cycle efficiency can be improved and the moisture content of the steam reduced by the addition of superheat at the turbine throttle. Figs. 2 and 3 illustrate the straight condensing cycle efficiencies and end-point moisture which can be realized in the low superheat and saturated-steam regions. Above 600 psi, the end-point moisture is excessive and the moisture correction factor used in the efficiency calculations questionable. Therefore, no data have been presented above this pressure for straight condensing cycles.

It will be noted that the addition of superheat at the throttle is desirable only if it is coupled with a parallel increase in the throttle temperature. With a given maximum throttle temperature (limited by the nuclear reactor), superheating at constant temperature at the expense of throttle pressure is detrimental to cycle efficiency, Fig. 2.

Therefore, a comparison of straight condensing cycles with saturated throttle steam against those with superheat for identical throttle temperatures indicates a thermodynamic advantage for the saturated-steam cycle provided the end-point moisture presents no limitation. In addition, the superheat cycle entails increased costs resulting from the heat exchanger surface requirements and thus leaves little, if any, justification for the superheat cycle.

If the throttle temperature is allowed to increase with the addition of superheat, it will be noted that there is a rate of change of throttle temperature to superheat which finally results in a cycle improvement even though the throttle pressure be allowed to decrease. The cycle efficiency will be improved still further as the rate of change of throttle temperature to superheat is increased, reaching a point where the throttle temperature to superheat is increased, reaching a point where the throttle pressure must be increased.

If the nonregenerative saturated-steam cycle with



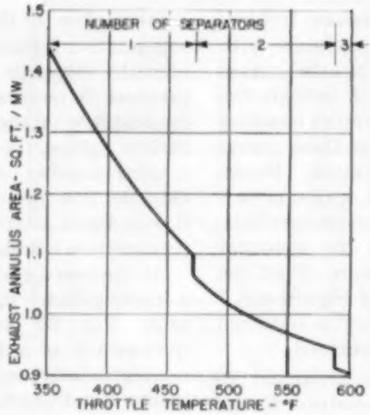


Fig. 12—Left, steam flow to throttle and condenser shows reduction in mass flow with lower temperature. Fig. 13 presents exhaust-annulus area needs.

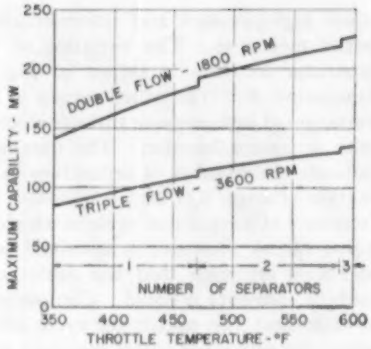


Fig. 14—Maximum capabilities with available annulus areas

a single moisture-separator stage (discussed in later paragraphs) is superimposed on Figs. 2 and 3, it will be found that the nonregenerative-separator saturated-steam-cycle efficiency is almost coincident with the 100 F superheat curve in Fig. 2, while the moisture is approximately coincident with the 200 F superheat curve in Fig. 3. On the assumption that plant costs are identical for either cycle, and that the throttle pressure is held constant, the superheat cycle requires a 100 F increase in throttle temperature to compete with the saturated-steam-separator cycle. Although no economic evaluation is presented, it is the authors' opinion that the superheat-cycle costs resulting from increased heat-exchanger surface, piping, radiation shielding and reactor cost, will exceed the cost of the moisture-separator installation, thus requiring a still higher throttle temperature to be competitive. In such an economic evaluation the increased turbine life resulting from the lower end-point moisture content of the saturated-steam-separator cycle also must be included.

Steam Reheater Versus Moisture Separator

Both the reheater and separator have large space and weight requirements, but the separator has the advantage of low cost and the possibility of inclusion within the confines of the turbine cylinder. The internal separator undoubtedly would reduce the requirements for space, the principal reason being that the large external piping would be eliminated.

A thermodynamic comparison of the steam reheater and separator nonregenerative cycles is presented in Fig. 4. The comparison is made at 150 psig and 600 psig saturated throttle-inlet conditions for one separator (reheater) stage. Curves *a* and *b* illustrate the reheat and separator cycles, respectively, both cycles drying the steam to a moisture content of 1 per cent. The curves indicate that if the reheater and moisture-separator installations are compared on the basis of identical thermodynamic conditions the separator is the obvious choice for reasons of lower cost and higher efficiency. An examination of Fig. 4 indicates that the maximum efficiency of the steam separator (single-stage) cycle occurs when the separator is located at 10 per cent of the throttle pressure. Fig. 5 further indicates that the efficiency peak is coincident with that separator location which results in an identical outlet moisture from both the high-pressure and low-pressure turbine elements. Later work, which is described in subsequent sections, indicates that the foregoing fact relative to the optimum turbine efficiency also holds true for multiple-separator applications.

If it is possible to reheat the steam to the initial throttle temperature, shown by curves *c* in Fig. 4, the steam reheater assumes the thermodynamic advantage. This results from the fact that the moisture separator can only dry (reheat) the steam up to the saturation line as the ideal limit. This comparison requires an economic evaluation to determine if the higher efficiency is sufficient to offset the cost differential between the separator and reheater installations. The increased cost of the reheater installation results from an increase in the reactor shielding, primary coolant holdup, reheater-surface requirements, valves and piping. It is the opinion of the authors that these costs in addition to considerations of space, weight and complexity are of such magnitude that the steam reheater cannot be justified.

Performance

It has been shown in previous sections that, with limited throttle temperatures, saturated-steam cycles with some means of moisture reduction rather than superheated-steam cycles should be employed. The discussion on the methods of moisture reduction indicated a preference for the steam separator. Therefore, the performance which is presented in the subsequent paragraphs will be confined to the saturated-steam cycle using separators. The intent of the work which follows is to establish a level of performance and to discuss the effect of the cycle parameters on performance.

The effect of location and number of separators on cycle efficiency for nonregenerative saturated-steam cycles in which the separator-outlet moisture is one per cent is shown in Fig. 6, while the effect on turbine-element-outlet moisture is presented in the left-hand column of Fig. 8. Similar curves for separators that deliver steam with five per cent moisture are shown in Fig. 7, and in the right-hand column of Fig. 8. In both of these figures the location of the high-pressure separator is given in terms of the throttle pressure. When multiple separators are employed, they are located so as to give

equal high-pressure and intermediate-pressure turbine-outlet moistures. The variation of this moisture with separator location is shown in Fig. 8 by the curves designated X. The other curves in Fig. 8 indicate the variation of low-pressure turbine-element-outlet moisture with separator location. The numbers on these curves indicate the number of separators in the cycle. Examination of Figs. 6, 7 and 8 indicates that optimum performance of a separator cycle in which all separators have equal outlet moisture is obtained when the separator locations are such that the outlet moisture of all the turbine elements is equal. Comparison of Figs. 6 and 7 reveals that the maximum cycle efficiency is obtained when the separator-outlet moisture is minimized.

All subsequent performance data are restricted to cycles in which the separator-outlet moisture is one per cent and the separators are located at the thermodynamic optimum positions without regard to design limitations. As indicated previously, the thermodynamic optimum arrangement is obtained when the inlet moisture to the separators is identical and equal to the outlet moisture of the low-pressure turbine element. For those cycles using one, two or three separators, the optimum high-pressure separator location will be approximately 10, 25 and 40 per cent of the throttle pressure, respectively, as is demonstrated by Fig. 6.

The optimum performance of nonregenerative saturated-steam cycles with one, two and three separators is shown in Fig. 9 as a function of throttle temperature. The improvement in performance brought about by the addition of separators to the straight condensing cycle is indicated in Fig. 9. The addition of a single separator not only improves the cycle efficiency but reduces the turbine-element moisture as well. Increasing the number of separators continues to reduce the turbine-element moisture and to improve the cycle efficiency. However, the improvement in performance becomes diminishingly smaller as the number of separators is increased above that required to limit the moisture to a reasonable value. The effect of back pressure on efficiency and moisture is presented in Fig. 10 with the minimum number of separators necessary at any steam condition to limit the moisture to an arbitrary value of 12 per cent. Lines A and B in the figures indicate the conditions where transition is made from one to two and from two to three separators, respectively. The remainder of the performance data is presented with the transition in number of separators at the conditions defined by Fig. 10 and with a back pressure of 1.5 in. Hg abs.

Performance of the regenerative steam cycles is given in Fig. 11 as a function of throttle temperature for various numbers of heaters and optimum final feedwater temperatures and separator locations. The regenerative-cycle gain in efficiency resulting from the addition of a heater at optimum final feedwater temperature is less than might be expected from experience with conventional cycles. This results from the fact that the separator cycle with zero heaters has included in it the regenerative effect from the separator drains. Because of the fewer number of turbine stages resulting from the reduced available energy of low-temperature steam cycles, the number of possible extraction points is limited. For this reason and because of the decreasing gain in performance from each additional heater, the maximum number of heaters considered in this paper is three.

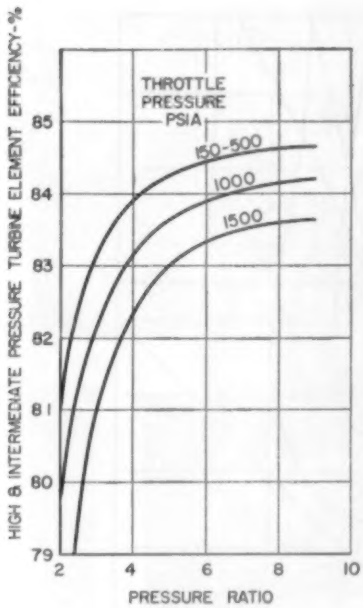
Steam flow to the throttle and condenser in the nonregenerative-separator cycle is shown in Fig. 12 and indicates the large reduction in mass flow as steam temperature is increased. Because of the direct effect of exhaust flow on the maximum capability of low-pressure-turbine cycles, the reduction in condenser flow with increased number of separators should be noted. The throttle flow would be increased and the condenser flow reduced relative to these nonregenerative values if regeneration is added.

As discussed earlier in the paper, exhaust-flow area is a limiting factor in the capability of a turbine-generator unit. Fig. 13 presents the exhaust-annulus-area requirements as a function of throttle temperature for nonregenerative-separator cycles. The area requirements are dependent upon the exhaust loss which was assumed to be 20 Btu/lb. With these annulus-area requirements, the maximum capability based on available present-day annulus area and turbine arrangements is shown in Fig. 14. It must be noted that greater output can be obtained at the expense of reduced efficiency by working the low-pressure end to its design limit.

Conclusion

The performance data as presented in the preceding section establish a level and trend which can be anticipated with present-day turbine practice. An examination of the performance of various cycles with due consideration to design limitations indicates that saturated-steam cycles with some means of moisture reduction rather than superheated-steam cycles should be utilized when the throttle temperature is limited. When compared at constant pressure, the saturated-steam cycle with separators is more efficient and less costly than a superheat cycle with up to about 100 F superheat. Somewhat above 100 F superheat, the efficiency of the superheat cycle increases sufficiently to overcome the cost advantage of the separator.

A comparison of the separator and reheat cycles on the basis of identical thermodynamic conditions indicates that the separator cycle is superior to the reheat cycle. When reheat to the throttle temperature is possible, the separator cycle continues to offer cost advantages over the reheat cycle and thus offsets the small improvement in efficiency of the reheat cycle. Optimum performance of a separator cycle in which separator-outlet moistures are equal is obtained when the separators are located so as to yield identical turbine-element-outlet moistures. Reduction of separator-outlet moisture to a minimum results in maximum efficiency. The performance further indicates that the number of separators probably should be restricted to the minimum number required to produce a tolerable level of turbine-element-outlet moisture. Methods of improving the utilization of the limited available energy of low-temperature steam conditions should be considered carefully. Regenerative feedwater heating is a method that offers considerable improvement in performance and increased capability. The use of drain coolers appears justifiable and forward pumping of the heater drains should be considered. The use of steam separators to improve cycle efficiency, increase maximum capability, and extend turbine life will help to make the utilization of low-temperature steam conditions from nuclear power sources economically justifiable.



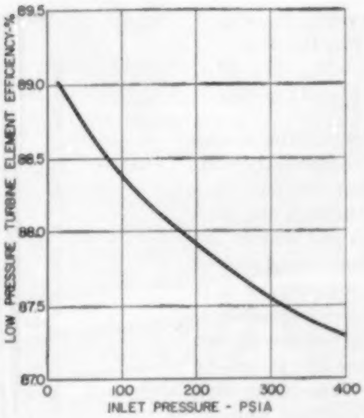


Fig. 16—Internal efficiency of low-pressure turbine element.

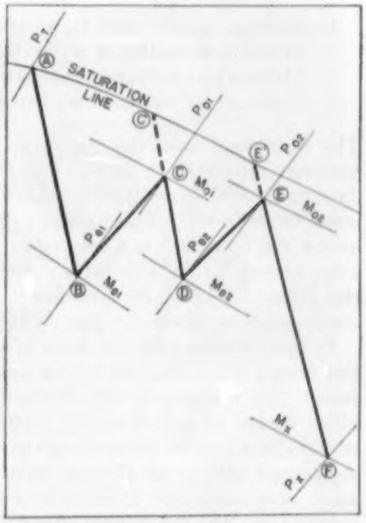


Fig. 15—Left, internal efficiency of high and intermediate pressure turbine elements and Fig. 17, right, a typical turbine expansion line on a Mollier diagram

Procedure for Determining Saturated Steam-Cycle Performance

Cycle Assumption. In order to present performance data, it is necessary to assume representative values for many of the significant factors which affect the performance of turbine-generator units.

The turbine internal efficiencies used in this study are shown in Figs. 15 and 16. These efficiencies are based on internal dry-stage efficiencies realized on units designed and built by the authors' company for application at elevated temperatures. To utilize these data in the region of saturated steam, a moisture correction of 1.2 per cent for each average per cent moisture was assumed to arrive at the final expansion line. In computing the average moisture in the low-pressure element, the moisture at the stateline end-point was used with the exhaust loss included.

The performance as presented in this paper is based on 3600-rpm units of 100-Mw capability. At this rating, the internal efficiencies of 1800-rpm and 3600-rpm turbine-generator units with identical steam conditions are essentially the same. For this reason, and because the leaving loss (Btu/lb) is assumed constant, the performance data as presented also may be applied to 1800-rpm units. Although the investigation was based on units of 100-Mw capability, the extension of these data to 200-Mw units introduces no appreciable error. In addition to the consideration of speed and unit rating, it must be recognized that the turbine-flow arrangement, whether tandem or cross compound, with variations in the number of low-pressure end, also will have an effect on the turbine efficiency. Although numerous combinations are possible, the resulting variations in cycle efficiency are well within the accuracy of the assumed turbine efficiency.

The exhaust loss is assumed to be constant at 20 Btu/lb which coincides with a leaving velocity from the last turbine stage of 1000 fps. This assumption implies a different exhaust end each time a cycle variation is introduced. A constant exhaust loss in Btu/lb was adopted for reasons of simplicity and suitability to modification in the event the reader wishes to introduce other exhaust losses in utilizing the performance data presented in this paper.

For all calculations, the assumed values of mechanical and generator efficiency are 99.0 per cent and 98.8 per cent, respectively. In computing the turbine-cycle efficiency, the pumping power is excluded in addition to any credit for feed-pump enthalpy rise. The drains from all steam separators are pumped directly into the feedwater for the nongenerative cycle or flashed to a feedwater heater in the regenerative cycles. The cycle arrangements are shown in Fig. 1. Where steam separators (or reheaters) are used a pressure drop of five per cent is assumed. The condenser-hotwell depression is taken as zero.

In all regenerative-cycle investigation, the feedwater-heater terminal difference is taken at +5 F and +10 F for the drain coolers. A pressure drop of 5 per cent is assumed between the turbine-extraction points and the feedwater heaters.

Approach. Fig. 17 shows a typical turbine-expansion line with moisture separators (two stages indicated). The partial expansion lines, CD and EF, have been extended to illustrate a single separator and straight condensing cycle, respectively. It is well to note that although the moisture separator is used as a basis for the discussion which follows, the story is equally applicable to a reheater.

With given throttle-inlet conditions and back pressure, points A and F in Fig. 17, there is an infinite number of turbine-expansion lines possible, dependent upon the variables necessary to define points B, C, D and E. The variables are as follows:

1—Pressure at entrance to separators—P_{e1}, P_{e2}, P_{e3}.
2—Pressure at outlet of separators—P_{o1}, P_{o2}, P_{o3}.
3—Moisture at entrance to separators—M_{e1}, M_{e2}, M_{e3}.
4—Moisture at outlet of separators—M_{o1}, M_{o2}, M_{o3}.

The numerical subscript refers to the separator stages numbered from the throttle. To make possible a thermodynamic-cycle investigation the number of variables must be reduced. The pressure drop through the separator (or reheater) was assumed to be 5 per cent of the inlet pressure to the separator thus eliminating one of the groups of pressure variables. For our purpose it is convenient to eliminate the outlet-pressure variable.

In conjunction with the slope of the turbine-expansion line which is established by turbine efficiency, it will be noted that fixing any two of the three remaining variables serves to establish the third. Thus the number of variables can be reduced to two times the number of separators with given throttle conditions and back pressure. For simplicity in the initial multiple-separator investigation, the moistures at the separator inlets were equal as was the moisture at the separator outlet. This procedure reduced the number of variables to two; the separator-inlet and outlet moistures. With this procedure the optimum separator location was found to exist where the low-pressure end-point moisture was identical to that at the separator inlets with all separator-outlet moistures identical.

This fact is illustrated graphically in the single-separator nonregenerative cycle by Figs. 4 and 5 which are discussed in the body of the paper. Since the state-line variables increase proportionately to the number of separators, it becomes quite difficult to illustrate this fact for the multiple-separator cases.

Fig. 18 presents a two-stage separator cycle based on 600-psia outlets. This curve was prepared to illustrate the effect of the separator locations on the cycle efficiency. The efficiencies are presented in the form of a contour map and show conclusively the great freedom of choice possible in the location of separators. Lines *A*, *B* and *C* are constant-moisture lines for the high-pressure-separator inlet, low-pressure-separator inlet, and turbine-exhaust end-point, respectively. The moisture content (99.2 per cent) for all these lines is the same, and it will be noted that their intersection approximates as well as can be determined the peak of the contour map. Line *X* was added to illustrate the path traversed

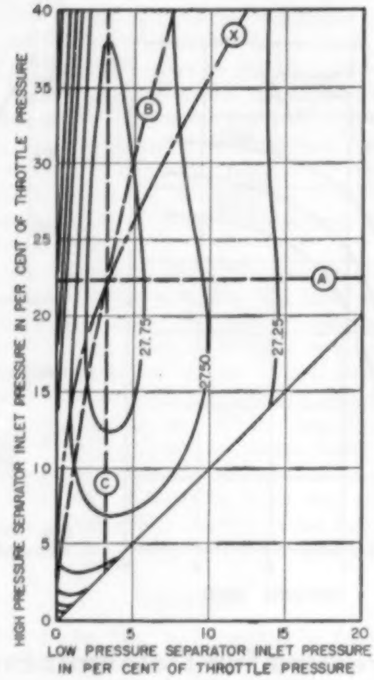
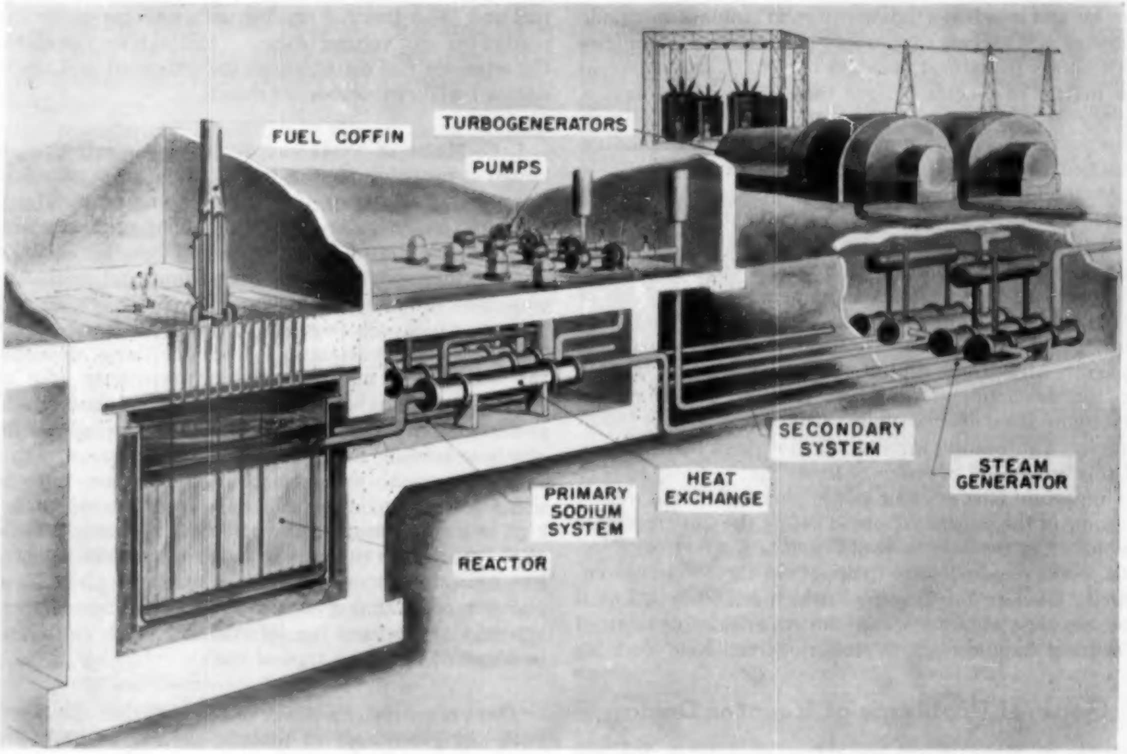


Fig. 18—Two stage separator cycle shows by contour map lines the effect of separator position on cycle efficiency.

in the preparation of Figs. 6, 7 and 8 presented in the body of the paper. Under this procedure the end-point moisture was allowed to deviate from the separator-inlet moistures which were all held equal. Again, it will be noted that locus X passes through the intersection of the identical moisture lines.

Based on the foregoing findings and the fact that the contour map is quite flat, the conclusion was drawn that the optimum expansion line between throttle conditions and back pressure will be found when the high-, intermediate- and low-pressure element partial expansion lines are bounded by constant moisture lines. It was assumed further in the remainder of the work that this fact would hold for all other steam conditions and multiple-separator cycles. The reader will appreciate the magnitude of the effort required to present conclusive evidence for all cases.

Having reached these conclusions, the final performance data were calculated on this basis and presented by plotting against throttle temperature. These data utilize the optimum thermodynamic-separator location without regard to turbine-design restrictions.



Sodium graphite reactor power plant proposed by North American Aviation, Inc.

Highlights of International Nuclear Engineering Congress

UNDER the sponsorship of the Nuclear Engineering Division of the American Institute of Chemical Engineers, with the University of Michigan acting as host, the first International Nuclear Engineering Congress was held at Ann Arbor on June 20–25. More than 1200 engineers and scientists representing 23 nations were registered for the Congress at which some 90 technical papers were presented. In addition to special events which featured addresses by outstanding leaders in the field of atomic energy, an "Atoms for Peace" Exposition was held, and the Michigan Memorial-Phoenix Project conducted a program entitled "The Atom Reports" which had as its emphasis the social impact of atomic energy.

Overall theme for the meeting was "Atoms for Peace," which made the selection of the University of Michigan as host for the International Congress particularly appropriate. In searching for a way to honor the memory of University of Michigan students and alumni who gave up their lives in World War II, the Michigan Memorial-Phoenix Project was conceived as a research program in peacetime uses of atomic energy. Now in its fifth year of activity, the Phoenix Project is studying such varied subjects as preserving food by radiological means, theoretical problems of nuclear reactor design, legal problems arising from the use of atomic energy and its impact upon public administration. Many of the sessions of the International Congress were concerned with these subjects, which were of considerable interest to visitors from nations all over the world.

Keynoting the "Atoms for Peace" theme was the banquet address by **Gordon E. Dean,** former chairman of the U. S. Atomic Energy Commission. He stated that, with changes now being made in the Atomic Energy Act of 1946, we must make possible a bold interchange of information and materials pertaining to the peaceful uses of atomic energy. Being aware of the capacity and the desire of other countries to utilize the atom, he felt that free interchange of materials and technical skills with nations of the free world is necessary to realize the most good from atomic energy. He also urged that changes be made in the Atomic Energy Act of 1946 to permit American industrial firms to sell services and component parts for power reactors to other countries desiring to build them.

"Nuclear Development the World Over" was the topic of an address by **Oliver Townsend,** secretary of Atomic Industrial Forum, Inc., who sketched the current status of atomic energy developments around the world and described some of the factors which seem to influence importantly the rate at which this development is going forward. The primary limiting factor in determining

how far and how fast a nation can go in building an atomic industry is its access to a supply of uranium. Countries with access to natural uranium only have less choice in the matter of reactor designs than those which have a supply of enriched fuel and pure fissionable material, thus putting a premium on a nation's ability to produce enriched uranium and plutonium.

Abstracts of a substantial proportion of the papers presented before the Congress are presented to give our readers a picture of the scope of activity and investigations now being undertaken in nuclear engineering. It will be noted that some of the papers lie in the fields of reactor construction materials, heat transfer and fluid flow, waste disposal, and general problems of reactor design. All of these subjects have an important bearing on the development of power reactors but have not heretofore been dealt within specific terms in this publication. Our readers are invited to express their opinion of this broadened coverage of areas that promise to play an important part in steam power plants of the future.

Some of the papers presented before the Congress were published in the May issue of *Chemical Engineering Progress*. The remainder are to appear in three volumes entitled "Nuclear Engineering," which sell for $4.25 each and may be obtained from the American Institute of Chemical Engineers, 25 West 45th Street, New York 36.

General Problems of Reactor Design

"The Role of Exponential Experiments in Reactor Design" was the subject of a paper by **E. R. Cohen** of North American Aviation, Inc. The exponential experiment represents a tool by which preliminary broad parameter surveys may be carried out on contemplated reactor core designs. A partial reactor, whose physical dimensions are too small to sustain a chain reaction, provides an operating milieu for the reactor components. A neutron source (low power reactor) provides the "driving force" and the geometrical configuration of the test region is controlled in order to reduce the complexity of the interpretation. The theory of the exponential experiment and the procedure of data reduction is outlined.

Other types of experiments, not strictly "exponential" in character, but which yield important data in reactor design are easily adapted to the exponential facilities. These include measurement of neutron density variations inside uranium fuel rods and in the moderator in between rods, measurements of diffusion coefficients, diffusion areas and neutron ages.

In a paper entitled "Non-Uniform Distributions in Nuclear Reactors," **G. Goertzel** and **W. A. Loeb** of Nuclear Development Associates, Inc., stated that in the majority of reactor designs the materials are distributed in a uniform pattern within the reactor. This uniform material distribution seldom results in a desirable distribution of other important performance parameters such as critical mass, heat generation or coolant temperature rise. It is pointed out that rather appreciable advantages may be gained by a deliberate redistribution of fuel, coolant or poison materials.

Three examples are given: (1) a fast reactor with uniform power generation per coolant passage, (2) a thermal reactor with uniform power generation per unit mass of fuel and (3) a thermal reactor with uniform power generation per unit volume of core. Methods for calculating the requisite fuel distributions are indicated and the resulting fuel distributions are shown.

J. C. Moise of Pratt and Whitney Aircraft Co. presented a paper under the title, "Application of Analog Computer Techniques to Reactor Dynamic Analysis." Dynamic analysis of a power producing nuclear reactor involves solution of both the reactor kinetic equations and the thermodynamic, hydrodynamic and mechanical equations describing the dynamics of all system components which influence the reactor's nuclear behavior. The non-nuclear equations include those describing the behavior of materials within the reactor core and those describing the dynamics of external system components which are coupled to the reactor through the flow of a heat transfer fluid. Typical components of such an external system are heat exchangers, pumps, transmission lines and turbines. Since the complete system is of high order and may include nonlinearities, hand solution of the resulting equations would be extremely time-consuming if not impossible. This paper describes the application of an analog computer to the solution of such a system and discusses the information which can readily be obtained from this type of work.

There is generally a choice of coolants that can be used with any given type of reactor, the most suitable one being dependent on the application of the reactor. **T. T. Shimazaki** of North American Aviation, Inc. discussed this subject in a paper entitled "A Comparative Evaluation of Some Coolants for Power Reactors." He stated that for a reactor of a central station nuclear power plant the basis for the choice of a reactor coolant would be lowest power cost consistent with technical feasibility. A comparison of power cost for some coolants that can be used in a graphite moderated, fixed solid-fuel reactor of a central station steam power plant is presented. The desirable characteristics of coolants for such a reactor are: melting point less than 550 F, boiling point higher than 1200 F, low cost, containable by a conventional structural metal, low neutron absorption cross section, high heat transfer coefficient, low pumping power, moderating power, thermal stability, radiation stability, low induced radioactivity and non-violent reaction with water. Among the possible coolants, sodium, bismuth, lead-bismuth eutectic and the salt, 40 per cent $NaNO_2$–7 per cent $NaNO_3$–53 per cent KNO_3, offer the possibility of power at comparable cost, and lead-magnesium eutectic offers the possibility of power at a cost somewhat lower than sodium. Technical problems or investigative efforts of fairly large order are associated with the use of all these coolants except sodium.

Development of Power Reactors

In a paper entitled "Problems of Power Reactor Design" by **W. E. Abbott** of North American Aviation, Inc., a projected cost structure for 6-mill electric power is given. This includes investment charges for the reactor, the cooling system and the power conversion equipment and operating charges for fuel and for operation and maintenance. Values are derived for the fuel

investment charge and the "burned" fuel cost. The effects of reactor specific power, plant availability and thermal efficiency on the various cost elements are discussed.

The desirable characteristics of nuclear fuels, moderators, reactor structural and shield materials, and coolants are described from the standpoint of the reactor designer. Prices he may be willing to pay for various materials are developed, based on typical parameters for a sodium-graphite, low enrichment uranium system. The importance of the cooling system is discussed and unit equipment costs are derived which make possible generation of competitive electric power with a sodium-graphite reactor power plant.

S. E. Beall and **C. E. Winters** of Oak Ridge National Laboratory presented information on the homogeneous reactor experiment carried on at that laboratory over a two-year period. This is a pilot plant using an aqueous solution of uranium as fuel. The heat-producing chain reaction occurred in an 18-in. diameter sphere, and heat was removed by pumping the liquid fuel through a U-tube heat exchanger where steam was generated and fed to a small turbine-generator unit. When the reactor was operated at 1000 kw heat output at 482 F and 1000 psi, a sufficient quantity of 200 psi steam was produced to generate 140 kw electricity.

The inherent safety of the reactor, as a result of its large negative temperature coefficient, was demonstrated by increasing the power by a factor of 10^6 in one second. Although no mechanical control devices were used, safe equilibrium condition was reached in 100 milliseconds.

Four steps must be taken before nuclear power conquers the problem of cost and is accepted for large scale use in the power industry, according to **Titus Le Clair,** Commonwealth Edison Co., Chicago. Discussing the economic approach to nuclear power he stated that the four steps are:

1. Experience must be gained in the operation of a nuclear power plant to permit a lower cost plant design and less conservative site selection.
2. The various parts that go into a nuclear power plant must be developed so as to reduce capital costs.
3. The original cost of fuel elements must be brought down.
4. Long "burn-up" of fuel must be accomplished.

The fastest way to achieve this will be to build and operate a reactor large enough to run a number of elements a long time for development purposes.

He said Commonwealth Edison's studies have shown that nuclear power can be a reality in the near future. To be economically competitive, however, the fixed charges on the plant must be reduced. Power companies who are considering the building of nuclear power plants will only have a real feeling of confidence to proceed after the first full scale plant has been built and opened for inspection. This is the indispensable step between the laboratory and accepted large scale use in the power industry. The sooner this step is taken, the quicker will nuclear power come into widespread economic use.

"Appraisal of Reactor Systems for Central Station Power Plants" was the subject of a paper by **Theodore Stern** of Foster Wheeler Corp. A method of applying a common denominator for economic comparison studies of nuclear power plants is described. Cost accounting rules are set which help compare all the reactor systems on the same basis. The rules, for uniformity, define development and material costs, land requirements, depreciation, return on investment, contingencies and overhead.

The method of applying a common denominator is illustrated by an actual comparison of reactor types to determine those systems that can be developed to generate economic nuclear power. The reactor systems considered in this appraisal are a pressurized water reactor, a fast plutonium breeder and an aqueous power breeder.

The results of the evaluation show that all of these systems have good possibilities of being able to compete with conventional steam plants, although considerable development work is still required to make the costs of power low enough to interest private capital.

There are a number of difficulties in the comparison of different reactor designs, according to **F. T. Miles** and **Irving Kaplan** of Brookhaven National Laboratory, who presented a paper entitled "Optimizing and Comparing Reactor Designs." Reactors for different purposes cannot be directly compared. Some designs consider the reactor alone, while others include the necessary reprocessing. One design may consider the use and processing of a single batch of fuel while another considers an eventual steady-state operation. Questions of availability of uranium, waste storage, and of necessary isotope enrichment are important.

The procedure adopted in this paper is to set up several balance sheets or systems of accounting. These kinds of economy may conveniently be considered in the following order: neutron economy; fissionable material economy; total heat rate; useful power; dollar economy; and long range conservation of energy sources. Choice of criteria is traced through the past history of reactor development and possible future trends are examined.

Materials of Reactor Construction

"The Technology and Fabrication of Graphite" was the title of a paper by **L. D. Loch** and **J. A. Slyh** of Battelle Memorial Institute. Graphite products have been used widely in nuclear development and production, chiefly as reactor moderators and reflectors and as crucible materials for special metals and alloys. Also, considerable progress has been made in developing graphite for fuel-element matrices for high-temperature power reactors.

Graphite products are produced commercially from selected combinations of many different raw materials. Most frequently, however, a petroleum-coke filler is used with a coal-tar pitch binder. The two materials are mixed and formed into shape at temperatures high enough to impart plasticity to the binder. Forming may be by extrusion or by molding. The products are gas baked and then graphitized at temperatures between 4500 F and 5500 F.

The properties of graphite which are of particular interest in reactor technology are low thermal-neutron-absorption cross section, high moderating ratio, high sublimation temperature, good thermal conductivity,

excellent resistance to thermal shock, high strength and resistance to creep at very high temperatures.

J. W. Holladay and **J. G. Kura** of Battelle Memorial Institute presented a paper entitled "Melting and Fabrication of Zirconium." Excellent corrosion resistance and ready workability make zirconium attractive as a new structural material. Because of its reactivity with atmospheric gases and all known crucible refractories, zirconium must be consolidated by the special technique of arc melting in a furnace equipped with a water-cooled copper crucible. For production of large-scale ingots, a consumable electrode is preferable to an inert electrode.

Zirconium can be forged and rolled readily in air with conventional equipment. It can be extruded to rod and tubing and can also be spun, cupped and drawn. Machining characteristics are similar to those of aluminum. Joining is achieved by soldering, brazing and welding.

Zirconium may be contaminated by oxygen, nitrogen, carbon or hydrogen during processing. Oxygen, nitrogen and carbon strengthen zirconium at room temperature, but the strengthening is lost upon heating to relatively low temperatures. Consequently, zirconium has good hot-working characteristics.

Resistance to corrosion of zirconium is excellent in acid, alkali and metal chlorides. Its resistance to hydrochloric and phosphoric acids is outstanding, but it is not resistant to sulfuric acid in concentrations exceeding 80 per cent.

"Radiation Effects on Structural Materials" was the subject of a paper by **C. R. Sutton** and **D. O. Leeser** of Argonne National Laboratory who stated that resistance to radiation damage is the new criterion on which the performance of engineering materials for reactor construction is being judged.

Their report is said to be the first open publication on actual experimental test results obtained on materials exposed to radiation damage. Since nuclear reactors are specialized engineering structures, it becomes increasingly important to understand and to evaluate these properties.

The two said that test data indicated that properties such as hardness, strength, mechanical and electrical resistance are affected. The degree of change appears related to the original condition of the particular materials as well as to the radiation dosage and exposure temperature.

Sutton and Leeser reported that, in general, materials show higher yield strengths, lower percentage elongation and somewhat higher ductile-brittle transition temperatures. The temperature of irradiation appears to be important to the degree that annealing or tempering takes place. In other words, those samples which are irradiated at elevated temperatures show less effect than do those irradiated at essentially room temperature.

They pointed out, however, that, since reactors have been in successful operation for some years, there is indirect proof that the reactor radiation effects are not catastrophic. However, they emphasized that irradiation effects are real and must be determined quantitatively for design use.

Heavy water, or deuterium oxide, is an important material for construction of reactors. Recently several of the methods for large-scale production have been declassified. **P. J. Selak** and **J. Finke** of the Savannah River Operations Office of the AEC presented a review of the water-distillation process with electrolytic final concentration, hydrogen-water exchange with an electrolytic finishing plant and the liquid hydrogen distillation process. The authors expressed the view that the marginal cost for heavy water for economical production of nuclear power is about $40 per lb. Unit costs currently reported in this country and Europe have ranged from $60 to $100 per lb, but it is felt that further development and improvements in plant design may bring the cost of heavy water below $40 per lb.

In a paper entitled "Radiation Damage to Water," **A. O. Allen** of Brookhaven National Laboratory stated that water may decompose under radiation to give hydrogen and oxygen gases and small amounts of hydrogen peroxide. The amount of decomposition depends critically on the nature of the radiation, the kind and amount of dissolved materials present and the temperature. Destruction of dissolved material may proceed to a greater extent than that of the water itself. The basic theory of these effects is briefly outlined. Engineering problems resulting from radiation chemical effects in water are discussed for various cases in which ordinary or heavy water is used in reactors as moderator, coolant or shielding material.

Heat Transfer and Fluid Flow

"Heat Transfer to Supercritical Water and Other Fluids with Temperature-Dependent Properties" was the title of a paper by **Kurt Goldman** of Nuclear Development Associates. A new method of analysis is proposed which may be used to predict heat transfer and pressure drop characteristics for fluids with temperature-dependent properties in fully developed turbulent flow. The new method is a further extension of the Reynolds analogy, and its later modifications, between turbulent momentum exchange and heat transfer.

Results obtained with the proposed method are shown to be in good agreement with experimental data obtained for air under high heat fluxes. The proposed method has also been used to predict heat transfer and pressure drop characteristics for water at 5000 psi flowing turbulently through round tubes. The results are given in graphical form relating useful heat transfer and shear stress parameters to bulk and wall temperatures.

S. L. Fawcett and **R. E. Grimble** of Battelle Memorial Institute, in a paper entitled "Use of the Cyclic Heat-Temperature Variation Method for Measurement of Reactor Heat-Transfer Coefficients," stated that this method provides a means of determining the heat-transfer characteristics of a flow system without requiring either the measurement of passage wall temperature or a detailed knowledge of the geometry of the flow system. Thus, the cyclic method is ideally suited to perform many services in the development and operation of nuclear reactors which would be very difficult, if not impossible, to do in any other way.

The unique requirements of reactor systems often result in a reactor core design with fuel elements surrounded

by irregularly shaped coolant passages. Examples of these are pebble beds, noncylindrical rods and mesh configurations. The cyclic method offers a rapid and economical way to measure the average heat-transfer coefficients of such configurations. The data so obtained are useful in design calculations and also in comparing different proposed core systems.

During the life of a reactor, it is desirable to determine periodically the amount of corrosion or scale build-up on fuel elements and the effect on the heat transfer. For this purpose, the cyclic heat-transfer technique may be applied in several ways. From cyclic measurements of a removed subassembly, and comparison with a clean subassembly, the average amount of scale build-up may be inferred. Another way to obtain similar information is by cycling the power level of the reactor in operation and measuring of the consequent effluent temperature cycles.

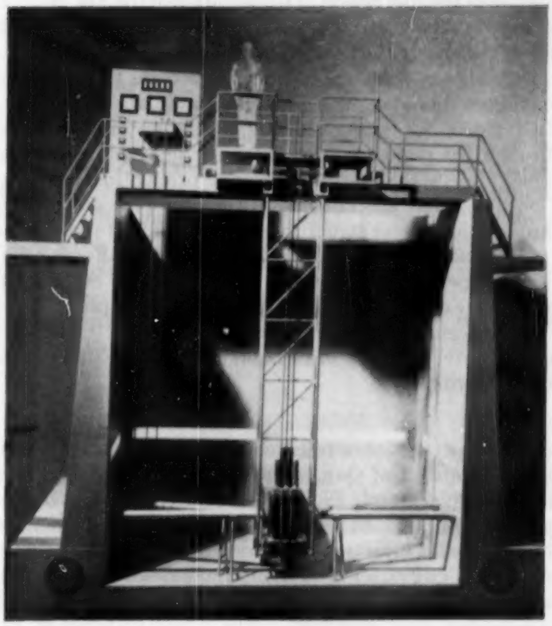
The usefulness of the cyclic method is not limited to reactor core applications. It may be used just as effectively to evaluate the heat-transfer characteristics of any component in the reactor heat-exchange system.

"Principles of Heat Removal from Nuclear Reactors" was the title of a paper by **William A. Loeb** of Nuclear Development Associates. There has been much discussion in the nuclear reactor field regarding the possible conflict between high coolant outlet temperature and high rates of energy removal. Behind this possible conflict lie the basic mechanisms of heat removal—heat transfer and heat transport. It is pointed out that it is the interaction of these two mechanisms that determines the extent of the conflict. Application of these principles to a particular case is outlined. It is also pointed out that solid coolants, having high volumetric specific heats, may, under certain conditions, prove superior to more conventional liquid coolants.

Another member of the Battelle staff, **E. M. Simons,** presented a paper entitled "Engineering Problems Pertinent to the Use of NaOH in Reactors." Anhydrous molten sodium hydroxide, because of its low vapor pressure at moderately high temperatures, rather small cross section for the capture of thermal neutrons, and substantial hydrogen content for neutron moderation has considerable promise as a reactor liquid. It could be used as a moderator alone in an enriched reactor; as a coolant; or, with the addition of nuclear fuel in the form of a solution or slurry, as the combined fuel-moderator-coolant in a homogeneous reactor.

Chemical plant experience with anhydrous NaOH has been limited to more or less static, open systems with temperatures not much higher than 180 deg F above the melting point. A host of new and difficult engineering problems are encountered in the design of closed circulating systems for temperatures up to 1500 F. Included in this paper are discussions of the search for suitable container materials; components for high-temperature hydroxide systems, e.g., pumps, seals, bearings, valves and plumbing; and instrumentation for such systems.

Another engineering problem is that of starting up or shutting down a reactor using sodium hydroxide, which melts at 605 F. Several possible methods of charging the system and keeping the hydroxide molten are discussed.



Scale model of atomic research reactor illustrating unitized construction and displayed at the "Atoms for Peace" Exposition by American Machine & Foundry Co.

Reactors for Research and Education

In a paper entitled "Research Reactor Program at the Pennsylvania State University," **William M. Breazeale** of that institution stated that a proposal had been placed before the AEC covering the design and construction of a research reactor, using school funds, and requesting that the Commission make the necessary fuel available. If the proposal is accepted, the school plans to build a modified swimming pool type of reactor. The chief change is that the facility will contain several horizontal beam holes for neutron diffraction work.

The staff expects that the uses for the reactor will fall into three main categories: analytical work, research and instruction. Basic facilities for experiments will be provided by the facility but individual experimenters will supply their own specialized equipment.

It is hoped that the facility will be completed and in operation within a year from the date of the Comission's acceptance of the School's proposal.

J. T. Weills of Argonne National Laboratory presented a description of Research Reactor CP-5 now nearing completion at that laboratory. It is of the enriched uranium heavy-water type and is expected to have a thermal neutron intensity 40 times as great as an earlier reactor which it is replacing. This improvement is brought about by selecting a fuel arrangement leading to a low critical mass and by providing for forced circulation cooling. The fuel is dispersed in aluminum plates 2 ft high. Ten plates are in an assembly through which the heavy water passes. Twelve of the assemblies are grouped to form a 2-ft dia cylinder at the center of a 6-ft dia aluminum tank filled with heavy water. Although this fuel core is only about 4 per cent of the

volume of the fuel region in the earlier reactor, the volume of high quality neutron intensity is large because the peak flux is outside of the core.

Eight beam holes approach or penetrate the region of maximum flux along the horizontal midplane of the core. Two tubes for pneumatically actuated samples pass through the region of high intensity just below the fuel zone. Below these are two isotope production facilities. Two holes that are tangent to the core pass completely through the reactor structure. A 2-ft-thick graphite zone around and below the tank of heavy water affords additional experimental volume. Two neutron or thermal columns extend horizontally from the graphite zone. Four concentric rings of vertical holes penetrating the heavy water and graphite regions complete the experimental facilities.

A high performance research reactor designed by members of the staff of Oak Ridge National Laboratory was described by **Joseph P. Gill,** who stated that the underlying philosophy is to provide the highest thermal neutron flux per dollar invested. The design utilizes an enriched uranium, light water-cooled and moderated system similar to the MTR (Materials Testing Reactor) and BSF (Swimming Pool Reactor). The novel features of the design include a completely removable beryllium reflector of minimum dimensions, the use of a water thermal shield and water-filled access holes and a control system actuated from below the reactor. The cost of this reactor, operating at power levels up to 10,000 kw and providing thermal neutron fluxes of the order of 10^{14} neutrons per sq cm per sec is estimated to be two and one-half million dollars.

E. T. Jurney of Los Alamos Scientific Laboratory presented a paper entitled "The Failure and Disassembly of the Los Alamos Fast Reactor." This was a low power (approximately 20-kw) research reactor capable of delivering a fast neutron flux of about 10^{12} neutrons per sq cm per sec. Its core region consisted of a lattice arrangement of metallic plutonium fuel rods surrounded by normal uranium reflector material and cooled by flowing mercury. Control of the reactor was effected by varying the reflector geometry. Experimental facilities consisted of numerous fast neutron ports and a graphite thermal column. Full power operation of the reactor began in 1949.

In December 1952, it became evident that a fuel rod rupture had taken place in the reactor, thereby releasing plutonium into the mercury coolant. This failure and indications of serious abnormal behavior of the reflector material created a hazard in the further operation of the reactor and prompted the decision to proceed with a complete disassembly.

Special techniques were employed in the disassembly to minimize the hazards encountered with the handling of free plutonium and fairly large amounts of radioactivity. The unloading and storing of the fuel and the contaminated mercury was done with the aid of dry-boxes, and some of the operations were also done with remote handling systems. After the core region was unloaded and sealed off, the reactor shield was completely removed and the uranium reflector was taken away as a unit.

Liquid Metal Fuel Reactor

The preliminary design of a nuclear reactor system which could generate electric power, "breed" new fuel for itself, and deliver by-products to waste tanks, all in continuous processes, was described by **Clarke Williams** and **F. T. Miles** of the Atomic Energy Commission's Brookhaven Laboratory in a paper entitled "Liquid Metal Fuel Reactor Systems for Power." The system, known as LMFR, would provide the first usage of a liquid metal alloy, in this case uranium-bismuth, as the fuel stream to interconnect continuous processes. The uranium used would be of atomic weight 233, a variety, or isotope, capable of splitting, or fissioning, as does the more commonly known U235.

Fission of the U233 atoms would occur in the LMFR core, a perforated graphite sphere five feet in diameter. Considerable heat would be given off in the fission process, and would be promptly conveyed by the molten uranium-bismuth alloy out of the core. To keep alloy inventory low, this substance would transfer its heat to liquid sodium outside the reactor proper.

Perhaps the most important feature of the LMFR is the integration of continuous chemical processing with the reactor. When a heavy atom like U233 fissions, each fragment, approximately half of the uranium atom, is a newly created element of intermediate weight. Some of these new products of fission appear as gases. Therefore, in one LMFR process, part of the molten uranium-bismuth would be piped off for removal of such gases as xenon and iodine, by "sweeping" them out of the liquid metal with an inert gas such as helium.

In another process, liquid salts such as potassium and lithium chloride could be mixed continuously with the bismuth carrier. The salts would draw off fission products while leaving the uranium in the bismuth. While gaseous and liquid fission products are piped into storage tanks, uranium-bearing bismuth would be pumped back through the core to continue the production of heat.

The authors listed several advantages which LMFR design offers as a source of power. Bismuth is impervious to radiation damage, and transfers heat efficiently. As a result, enough fuel could be introduced into the core to provide a chain reaction which would produce large amounts of heat. Thus, with proper economy, excess neutrons would be available for capture in the blanket. Here, because of continuous recycling of thorium, all of it could be bred into U233, providing fuel at low cost. Continuous processing out of fission products would provide important cost reductions over present methods.

"Heat Exchange in a Liquid Metal Fuel Reactor for Power" by **Orrington E. Dwyer,** also of Brookhaven, explains the relationship of neutron economy, corrosion, erosion and mechanical design to the efficiency with which heat is generated in an LMFR core and converted to power. On the basis of experiments, calculations and theory, the paper summarized the advantages and disadvantages of internal versus external cooling in an LMFR. In the former, the fuel (uranium) can remain inside the core and therein transfer its heat to a primary coolant (bismuth). In the latter, the liquid bismuth-uranium can be circulated continuously to external heat exchangers, where it can transfer its heat to a secondary

coolant (sodium). In the internally cooled system the primary, and in the externally cooled system the secondary, coolant converts water into steam to generate power.

A survey of solutions of uranium and thorium liquid metals and dispersions of uranium thorium compounds in liquid metals has led to the discovery of several fuel and breeder systems useful in reactor design, according to a paper entitled "Liquid Metal Fuels and Liquid Metal Breeder Blankets," by **R. J. Teitel, D. H. Gurinsky** and **J. S. Bryner** of Brookhaven. A solution of uranium in bismuth and a dispersion of a uranium-tin compound in lead-bismuth-tin alloys have been proposed for two reactor designs, an externally and internally cooled reactor design, respectively. A thorium-bismuth compound dispersed in bismuth and lead-bismuth has been suggested for a breeder blanket in both reactor designs.

This paper describes some of the properties of liquid metal fuel and breeder systems. It introduces the concept of using intermetallic compounds dispersed in liquid metals for these applications. Preparation steps for these are described.

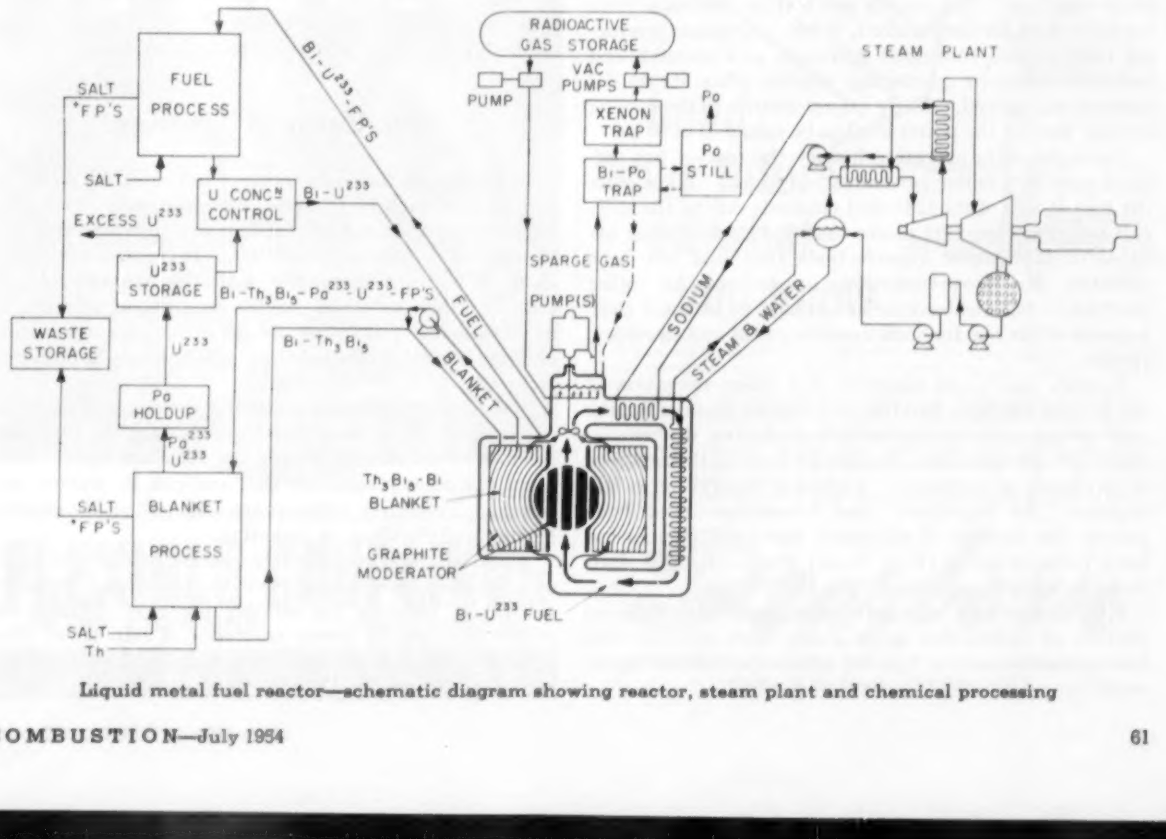
"Studies in the Uranium-Bismuth Fuel System," by **J. F. Atherton, D. H. Gurinsky, O. F. Kammerer, C. J. Klamut, Melvin Silberberg, Bernard Turovlin** and **J. R. Weeks** of Brookhaven was a paper based on experimental work in which several steel pipes shaped in circular loops known as "harps" were filled with bismuth-uranium fuel. Each loop was subjected to high temperature on one side, to correspond to the heat the fuel would carry as it left the LMFR core.

In some iron-chromium alloy containers, the fuel dissolved away so much of the container alloy that the loop became plugged up. Addition of zirconium and magnesium to the fuel virtually eliminated corrosion of container alloys. Also, by making a tiny amount of the zirconium radioactive, it was determined that this material clings to the inside of the loop, thus retarding dissolution of iron into the fuel system.

Initial laboratory experiments in miniature established that a melted mixture of potassium chloride and lithium chloride will remove fission products from liquid bismuth without reacting with uranium present in the liquid. It thus becomes feasible, in an LMFR, to shunt fission products to storage or processing tanks, and return bismuth-uranium fuel to the reactor core. This subject was discussed by **D. W. Bareis, R. H. Wiswall, Jr.,** and **W. E. Winsche** in a paper entitled "The Processing of Liquid Bismuth Alloys by Fused Salts."

"Liquid Metal Fuel Reactor Processing Loops" by **Chad Raseman** and **Joel Weisman** of Brookhaven was a paper concerned with construction materials for fission product removal systems. Before accepting the method of using salts to extract gaseous and liquid fission products, it must be satisfactorily demonstrated in an experiment inside a reactor. However, it was necessary first to build and operate several out-of-reactor loops for the purpose of testing materials of construction, pumps, valves, instrumentation, methods of heating, methods of sampling, and many other components and processes, in order to insure the integrity of the in-reactor experiment.

Each loop constructed improved with regard to salt processing, operation during experiments, and length of continuous service. The fifth loop assembly has circulated fuel and removed fission products continuously, without interruption, during some 14,000 hours. A loop



Liquid metal fuel reactor—schematic diagram showing reactor, steam plant and chemical processing

assembly is now being completed for exhaustive testing in the Brookhaven reactor.

In the general description of LMFR by Messrs. Williams and Miles, the thorium-bismuth liquid which is pumped out of the breeder blanket is contacted with melted salts. Fission products are separated out, and thorium-bismuth returned to the blanket. A paper entitled "A Continuously Separating Breeder Blanket Using Thorium Fluoride" by **F. T. Miles, R. H. Wiswall, Jr., R. J. Heus** and **L. P. Hatch** of Brookhaven proposes an alternative process, in which a solid salt, thorium fluoride, is the blanket material. The products would be separated out as separate gases—on the basis of widely different fluoride volabilities—of the bred material.

In one series of experiments, a loop containing thorium fluoride was placed in the Brookhaven reactor, and uranium fluoride continuously removed. In one design under consideration the blanket is circulated outside the reactor for cooling and the thorium fluoride is processed in the flame of a fluorine torch.

Reactor Operation

Operation of a nuclear reactor is less complicated and less hazardous than the operation of many less impressive industrial machines, according to **M. E. Ramsey** and **C. D. Cagle** of the Oak Ridge National Laboratory. Their report was based on the experience with the Oak Ridge graphite-moderated normal uranium reactor, which began its 11th year as a continuously operating, dependable research and radioisotope-producing tool of science on Nov. 4, 1953.

Thousands of experiments and measurements of radiation and neutron bombardment effects have been performed during this time making this one of the most productive instruments of science in the early years of the atomic age. The reactor was built in 1943 as a 1000-kw pilot plant for the Hanford, Wash., plutonium producing reactors and continued operation as a research and radioactive-isotope producing reactor after its initial purpose was served. Early improvements in the cooling system allowed the power level to be raised to 3700 kw.

Throughout its operating history the reactor has suffered only two minor permanent damages. These were the loss of two of its 1248 fuel channels due to the difficulty in removing fuel pieces that had broken open because of fabrication imperfections that had not been detected during preinsertion inspection. All other troubles or failures have been confined to external components of the reactor such as cooling fans and electronic circuits.

Ramsey and Cagle reported that direct operation of the reactor has been handled in a routine manner for the past several years by high-school graduates, whereas initially the operation was thought to demand the presence of physicists or engineers. Technical supervision is still required. As experience and knowledge have been gained, the number of safeguard shutdown circuits has been reduced from 17 to 9 and the number of shutdown rods has been reduced from eight to five.

Experiences with radioactivity hazards have included releases of radioactive noble gases, dust particles and beams into the reactor building from experimental equipment but no injuries to personnel resulted.

Disposal of Radioactive Wastes

W. A. Rodger of Argonne National Laboratory presented a paper entitled "Treatment, Use and Ultimate Disposal of Radioactive Wastes." A short history of philosophy employed in the handling of radioactive wastes, since the inception of the industry, is used as a starting point for this paper.

The distribution of fission product acitivity at time of pile discharge is shown. To indicate the potential magnitude of the problem, the accumulation of several long-lived isotopes over fifty years for various assumed rates of production is estimated. Allowable air and water tolerances for several isotopes are presented and some necessary dispersal areas calculated.

Potential waste volume accumulations are estimated, and various types of storage are discussed.

Two things are clear. Some ultimate disposal method must be found. Liquid storage is not it. A reduction to solids is necessary. Various proposals for doing this are described and assessed.

The channeling of fission products into industrial use is discussed as a means of reducing the magnitude of the disposal problem but not as a final solution.

Two possible methods of disposing of radioactive waste products of reactors at off-site points were described by **Bernard Manowitz** and **L. P. Hatch** of Brookhaven National Laboratory in a paper entitled "Processes for High-Level Waste Disposal."

One method they described involves evaporating the waste to dryness and fusing it into a solid mass, all within disposable containers. The second method involves the adsorption of fission products ions on montmorillonite clay and the fixation of these ions by heating the clay to high temperature.

The authors report that current disposal methods which involve liquid storage in large underground tanks are inadequate for any future reactor sites in populated areas, and are, in fact, inadequate as a permanent disposal methods even for AEC sites in uninhabited localities.

Metallurgy of Uranium

In discussing the metallurgy of uranium, **H. A. Saller** and **F. A. Rough** of Battelle Memorial Institute stated that the development of uranium has been handicapped by some of its peculiar properties. It is extremely active chemically, reacting readily with the atmosphere and most crucible materials. Since uranium is anisotropic, its mechanical properties are dependent on orientation and are greatly affected by variations in fabricating techniques.

Satisfactory methods for melting, casting, and fabricating uranium have been developed to a state that any number of fabricated shapes are now available. Uranium machines reasonably well and can be welded and brazed. Protective coatings may be put on by electroplating, roll cladding, or jacketing.

There has been considerable interest in uranium alloys as a means of increasing strength, improving corrosion resistance, lowering the melting point, or diluting enriched uranium for power reactors. A number of alloy systems have been studied extensively, and a large number of constitutional diagrams are available.

ASME Semi-Annual Meeting Convenes at Pittsburgh

OVER 1400 engineers attended the four-day Semi-Annual Meeting of the ASME in Pittsburgh, June 21–24. Among the highlights of the meeting were the announcements of the nominating committee's slate of officers for the year 1955, the Roy V. Wright lecture delivered by Raymond R. Tucker, mayor of St. Louis, Mo., luncheon talks by Lewis K. Sillcox, president of the ASME and Crosby Field, fellow of the ASME, and the main banquet speech by A. B. Van Buskirk, vice president, T. Mellon & Sons of Pittsburgh.

David W. R. Morgan, vice president on the headquarters staff of Westinghouse Electric Corp., was nominated for the post of president; James B. Jones, head of the mechanical engineering department of Virginia Polytechnic Institute, was selected for vice president, Region IV; Ben G. Elliott, chairman, department of mechanical engineering, University of Wisconsin, for vice president, Region VI; and C. H. Shumaker, chairman, department of industrial engineering, Southern Methodist, vice president, Region VIII. The following were chosen as candidates for directors-at-large: George A. Hawkins, professor of thermodynamics, Purdue University; Harold C. R. Carlson, president, The Carlson Co; Louis F. Polk, president, the Sheffield Corp.

The technical sessions covered a number of areas of interest. Only those sessions of interest to the power field are reported below.

Piping Design and Considerations

One of the principal jobs facing the designer of large central stations is the layout of the steam-piping system. The importance of this job has increased many-fold in the last few years and all indications point to its continuing its importance. The paper "Design of Steam Piping Systems for Large Central Stations Applications," by **R. L. Jackson** and **L. H. Johnson,** General Electric Co., pointed up the increasing complexity of this job and then suggested a method to produce more efficient designs and savings in initial costs.

The general practice is to make a layout of the piping connecting the end points by using intuition and to analyze the expansion reactions, taking into account movements of the end point. This check for flexibility if done by a full elastic analysis becomes very complex involving a number of simultaneous equations equal to six times the number of end points minus six plus additional ones for intermediate restraints. Many simplifying assumptions and short-cut methods have been devised but the authors feel a thorough flexibility study is not only a definite advantage but fast becoming a requisite.

One way of obtaining the necessary calculations quickly is to use punched-card calculating machines or some form of an electronic computer. A by-product of the knowledge these calculations give is the recognition of the extent of pipe movements so pipe hangers can be intelligently designed. Further, a system of restraints can be installed to protect smaller piping at the end of the main system from misoperation of the hangers.

A second paper on the same general subject, "Analysis of Pipe Systems with Special Expansion Features," by **J. E. Donahue,** Westinghouse Electric Corp., covered the devices for absorbing movements in a system. The devices resemble either a circular flat-plate, bellows-type expansion

joint or a toroid-type expansion joint with or without tie rods. A method for calculating the stresses in the piping system parts resulting from axial displacement, rotation and pressure was presented. In addition a method of determining in-plane and out-of-plane spring constants for the devices was suggested. With the facts this method produces the author believed the devices can be converted into an equivalent length of straight pipe. Then this equivalent length may be incorporated into any standard mathematical flexibility analysis for a piping system, and the total net end reactions and stress in the system evaluated.

As the author explained designers often follow custom or current practice. When thermal-expansion problems arise in moderate pressure systems many designers immediately specify a conventional bellows (flat-plate) type expansion joint. If the system has expansion parallel to the pipe only then one expansion joint is used. If expansions are both parallel and lateral to the axis of the pipe then two expansion joints spaced apart are used. But such a procedure involves assumptions that should not be made with high-pressure piping systems.

The author supplied a complete set of formulas for the analysis of a piping system.

Cooling Towers Vs. River Water

J. Lichtenstein and **B. C. Sprague,** Sante Fe Tank & Tower Co., presented some highly interesting observations on a current subject in their paper "Economic Comparison of River and Cooling Tower Circulating Water Systems."

The ratio of heat rejected to the condenser to the total heat entering the turbine has been steadily declining for steam-electric power plants. Not only has the relative cost of the equipment for heat rejection been reduced but the economics of power-plant location has also been affected so that the relative importance of locating plants along rivers, lakes, or other large bodies of water has diminished. So the question of cooling towers versus river location becomes an important one.

To compare the two systems it is first necessary to reduce them to a common economic basis. Of all the combinations included by the two systems the ones of least total costs must first be found. These total costs include equipment, capitalized costs of power requirements and system capability losses. The authors described a mathematical method and gave derived equations to calculate economic specifications for selecting the equipment of least costs.

The comparison between cooling towers and river plants, the authors claimed, always produces a price difference. But in most instances this differential can be eliminated or even made negative by various savings possible with cooling towers because of the relative freedom of choice.

Coal Storage

The appeal the bulldozer has for the power plant operator is that it answers very well the basic requirements of coal storage in meeting a reasonably level consumption value from a varying supply rate. In the paper by **D. K. Heiple,** Le Tourneau-Westinghouse Co., "Methods and Costs in Coal Storage With Scrapers and Bulldozers" this fundamental appeal was recognized and then developed in light of the special problems coal storage presented.

The advantages the bulldozer has, where the operator requires increased storage in already confined areas, were stressed and enumerated as follows: by adding to the coal pile height, by making full use of irregularly shaped storage sections, by imposing no demands for trackage, by compacting coal into maximum tonnage for a given volume by simply traveling over it in stacking operations.

Once the role of the bulldozer in coal storage had been established the author developed its costs of operation from the simple bulldozer using sheet metal blade extensions to specially designed scrapers with sideboards added. The working cycle both for stacking out and reclaiming were analyzed and costs per ton of coal handled were figured out. A number of illustrations were furnished of bulldozers at work.

Nuclear Reactors

The highly interesting field of nuclear reactors was presented by three papers covering different aspects. **C. R. Stahl,** Knolls Atomic Laboratory, in his paper "The Mechanical Design of Liquid Metal-Cooled Nuclear Reactors" began by emphasizing that the inexperience of all concerned had led to a fundamental analytical and experimental approach in designing all the equipment scheduled for nuclear energy projects. Yet the design of liquid-metal nuclear reactors, as a case in point, presented fundamentally a problem no different than any other design project.

With the completion of the SIR (submarine intermediate reactor) design by the author's company many of the critical design areas are known. The following points stand out as different from normal design: (*a*) nuclear requirements, (*b*) heat generations

and cooling, (*c*) thermal stresses, (*d*) mechanism problems.

Small changes in density, impurities and dimensions can affect seriously nuclear characteristics so the designer must place close chemical and mechanical tolerances on critical parts. These requirements were discussed in some detail.

The problems of heat generation and flow and the role of the coolant, such as a liquid metal, received considerable attention and a number of conditions were set up. Thermal stresses obviously entered into the considerations and the author included them in his discourse. Lastly the mechanism control phase was briefly touched upon.

N. J. Palladino, Westinghouse Atomic Division, chose "The Thermal Design of Nuclear Power Reactors" for his subject. In it he developed the relationships between maximum fuel-element surface temperatures, coolant temperature rise, flow, pumping power and operating steam temperatures for use in the design of a power-producing nuclear reactor.

The heat output of a nuclear reactor, according to Mr. Palladino, is generally limited by the maximum metal-surface temperature which in turn depends upon corrosion attacks or dangerous boiling conditions. Designing a reactor on the basis of maximum metal-surface temperatures becomes highly important since the heat is not generated uniformly throughout the reactor and because tolerances established for manufacturing purposes could introduce further increases in hot-spot temperatures.

The paper included a lengthy list of nomenclature, a discussion and a mathematical treatment of the design parameters, a coverage of the desirable properties of a coolant and a review of how some materials meet these desired points and a mathematical development of an expression for the allowable coolant temperature rise.

A third paper on the subject of nuclear reactors "Working-Stress Criteria for Nuclear Power Plants," by **B. F. Langer,** Westinghouse Atomic Division, confined itself to the twin problems of strength calculations to meet thermal stresses as well as fluid pressures.

Material selection for a nuclear reactor differs in the strength calculation phase from conventional heat-power or process equipment. The principal differences are the greater effect of thermal stresses and the frequent use of unfamiliar materials. In this paper the author presented a method to combine the stresses produced by fluid pressure with those developed by thermal gradients to arrive at a suitable factor of safety. The discussion

encompasses the relative design importance of ductility, creep, endurance limit, creep-rupture strength, impact-strength and notch sensitivity.

Gas Turbines

Two engineers outlined different adaptations of the gas turbine in industry. **Benjamin Miller,** consulting engineer, proposed a number of economies in his paper "Gas Turbine Processes Using Added Steam."

His computations showed that a conventional gas turbine rated 5700 hp at 25 per cent thermal efficiency can have its output increased to 7500 hp at 29 per cent thermal efficiency by adding steam generating equipment costing considerably less than one-fifth the cost of the gas turbine plant.

Hans Pfenninger, Brown-Boveri & Co., discussed "Operating Experience with Gas-Turbine Plants in the Steel Industry."

Mr. Pfenninger discussed the operating maintenance histories of gas turbines operating on blast furnace gas in the steel industry. Reviewing the records of these plants, he pointed out that the gas turbine shows real promise as a useful power plant for the steel industry, and that it can compete successfully with other prime movers.

A number of installations of gas turbines performing the duties of longer established prime movers were presented and operating results explained. Some of these traditional duties will definitely be usurped, according to the author, by the gas turbine because of its advantoges.

In conclusion the principal figures for a modern gas-turbine plant for power generation and fitted with a combined burner for blast furnace gas and oil-firing were offered. Such a plant for a 10,000 kw terminal output was said to cost in Europe about $90 per kw excluding the building costs but including steel foundations. The overall thermal efficiency amounts to

27 per cent. In addition the exhaust gases from the plant can raise 16 lb of steam at a pressure of 85 psig. If this steam production is included in the heat balance the overall thermal efficiency climbs to 36.5 per cent.

Air Pollution Studies

A three-paper session on air pollution studies confined itself primarily with stack discharge problems. **Gordon H. Strom** and **James Halitsky** of New York University examined the theoretical bases for wind-tunnel experiments on stack-gas pollution and presented the important variables and scale factors. Test results for the effects of these variables made an interesting part of the paper.

The authors discussed the test procedure in the New York University $3^1/_2$ by 7-ft. wind tunnel. Field data of a limited nature were collected and correlated with wind-tunnel results to given an indication of the accuracy of the wind-tunnel experiments.

George Haines and **W. C. L. Hemeon,** Industrial Hygiene Foundation, presented a pair of papers, "A New Method for Stack Dust Sampling" and "The Magnitude of Errors in Stack Dust Sampling."

In the latter paper the authors tackled the major errors that they believed existed in the small volume sampling category such as sampling rates from $^1/_2$ to 2 cu ft per minute. The one common method of using a filter disposed outside the duct or stack and a sampling tube connecting it to the nozzle proper was subject to a number of possible errors: hazards within the tube itself from dust deposits or corrosion of metal tube surface from sulfur gases and condensation, difficulties with the dust filter element, nozzle design problems, and inherent errors, departures from the true isokinetic velocities of sample gas within the sampling takeoff system whereby dust drops out before reaching the test point.

A number of valuable tables were given with the various errors presented by these factors listed therein.

As a result of the intensive studies by the authors on the magnitude of errors the natural followup of a proposed stack dust-sampling technique to overcome these errors was brought into existence. This proposal made up the second paper by the same authors.

Their earlier findings indicated that in the sampling of common stack dusts appreciable departures from the isokinetic sampling can be tolerated without significant error if the size of the gas sample is defined on the basis of approach velocity.

New Catalogs and Bulletins

Any of these may be secured by writing Combustion Publishing Company, 200 Madison Avenue, New York 16, N. Y.

Water Columns

A new product data unit, No. 232, describes, illustrates and gives specifications on the Jerguson Gage & Valve Co.'s water columns. The principle of operations and features that assure positive alarm signals if boiler water falls too low or rises too high are explained.

Heat Exchangers

The diversified heat exchanger products of the Davis Engineering Corp. are brought together for ready reference in a new 20-page Bulletin 1000 under the major headings of chemical, industrial, power plant, and marine. Full technical description of the exchangers accompanies the over fifty illustrations.

Pneumatic Transmitter

Low-head, differential-pressure pneumatic transmitter designed particularly for measuring liquid fuels, and the automatic control of the fuel-air ratio is described in the Hagan Corp.'s 4-page Bulletin 2753. Other features include construction details and cutaway view showing the specially designed no-sealing-fluid measuring assembly.

Monel Properties

A new 8-page technical booklet on the engineering properties of "S" Monel has just been issued by the Development and Research Div. of the International Nickel Co., Inc. This material is an age-hardenable casting alloy that provides strength, hardness and anti-galling properties at temperatures up to 1100 F in addition to the general corrosion resistance of Monel.

Emergency Lighting

Designed to assist architects, builders, contractors and engineers needing help in selecting emergency lighting equipment, the 4-page bulletin, Form 4808, put out by the Exide Industrial Div. of Electric Storage Battery Co. includes schematics, layouts and illustrations of typical installations and is supplemented by suggested specifications conforming with sections of the recently revised National Electrical Code for 6-volt emergency lighting equipment.

High Temperature Water

The highly interesting newcomer to the field of heat transfer, high temperature hot water, makes up the subject matter of a new 16-page bulletin, No. 100, now available through American Hydrotherm Corp. It discusses and illustrates applications in large area installations such as district heating, airports, hospitals, schools.

Lagging Adhesives

A rather special product in the field of shrinking, sizing, binding and protecting insulation, that of lagging adhesives, is covered in the 4-page technical bulletin, No. 5307 (A.I.A. File No. 37-D) published by the General Paint Corp. The bulletin describes the manufacturer's Adhez-A-Kote and details some of its applications.

High Alloy Castings

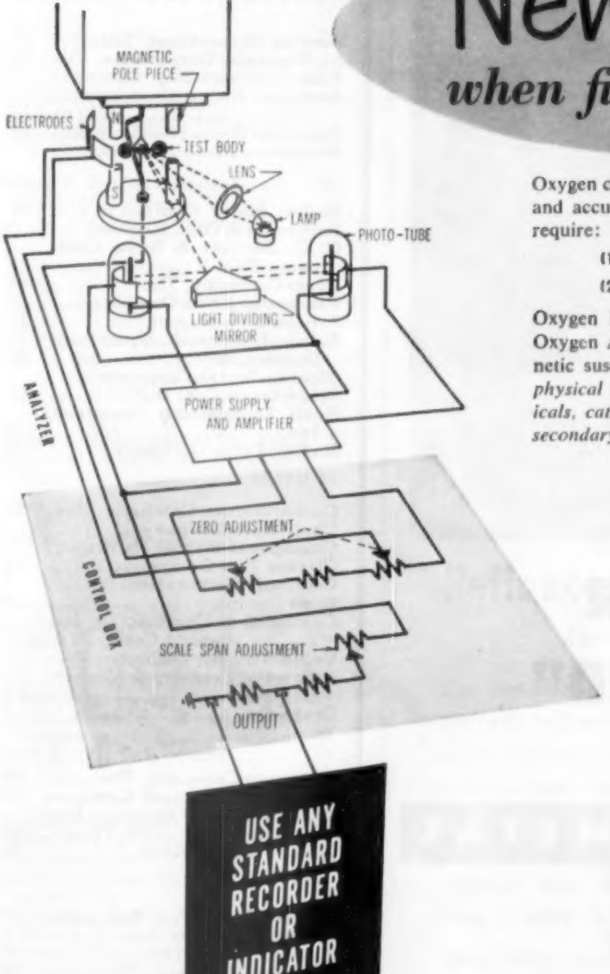
To aid designers in the use of high alloy castings, the Alloy Castings Institute has made available a 7-page reprint of the paper, "Resistance of Cast Fe-Cr-Ni Alloys to Oxidizing and Reducing Flue Gas Atmospheres" by J. H. Jackson, C. J. Slunder, O. E. Harder and J. T. Gow, presented originally before the ASME and appearing in August 1953 Transactions.

Pipe Machines

Selling features, dimensions, operating capacities, ordering specifications, dies available and accessories for five pipe machines and power drives appear in the new 16-page Power Machine Catalog of the Beaver Pipe Tools, Inc. A number of models are illustrated and described along with a universal nipple chuck as a featured accessory for all the manufacturer's power drives.

New Savings...

when firing with any fuel!



Oxygen content of the flue gases is generally recognized as the most direct and accurate index of correct air-fuel ratio. Optimum results, however, require:

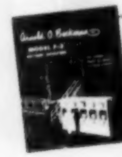
(1) An Analyzer that is accurate, dependable, field-proven.

(2) A Sampling System that is simple, responsive, trouble-free.

Oxygen has a high magnetic susceptibility. The Arnold O. Beckman Oxygen Analyzer is the ONLY oxygen analyzer that measures total magnetic susceptibility directly. It is the ONLY Analyzer providing a *direct physical* measurement of the oxygen content itself. *No filaments, chemicals, catalysts, glassware or other complications found in conventional secondary methods of measurement are required!*

As shown at left, a small dumbbell is suspended in a magnetic field. The sample gas surrounds this dumbbell. If the sample gas contains oxygen, it is drawn into the magnetic field, causing the dumbbell to rotate into or out of the magnetic field, *depending directly upon oxygen content of the gas itself.* A beam of light, reflected by a mirror attached to this dumbbell, actuates phototubes. With simple electrical circuits, the dumbbell is repositioned to its null point by a voltage. This voltage is proportional to the oxygen content and can operate any standard recorder or indicator. *It's as simple and positive as that!*

This revolutionary Analyzer permits a completely new approach in Arnold O. Beckman Sampling Systems and accessory equipment — systems carefully engineered to meet the most difficult requirements of the power industry. They are unusually simple, trouble-free, and readily adaptable to various operating requirements.



Get the full story on this remarkable new advancement in Oxygen Analyzers. Write for Data File 10-F-74. No obligation, of course.

Features of the Beckman Model F-3

SELECTIVITY Highly sensitive to oxygen. Effects of gases other than oxygen are negligible.

MANY RANGES Combustion ranges include 0-5%, 0-10%, 0-15%, and are provided with a second range of 0-25%. Other ranges up to 0-100% O_2 are available. Calibration of the Model F-3 is strictly linear and scale is accurate over the entire range.

HIGH ACCURACY ± 1% of full scale for spans of 5% and greater. Accuracies within .05% O_2 on 0-5% range are available.

AIR CHECK Simple positive check of proper operation by recording the air point on the second range.

SIMPLE SAMPLING Independent of flow rate. Nothing is added to the sample. The sample may be dry or saturated. Corrosive gases will not poison the instrument. Only a small sample (3-15 cu. in./min.) is required.

LOW MAINTENANCE Completely insulated against extreme shock and vibration. No chemicals, no catalysts to replenish. No wicks, filaments, orifices, valves, etc., to clean and replace.

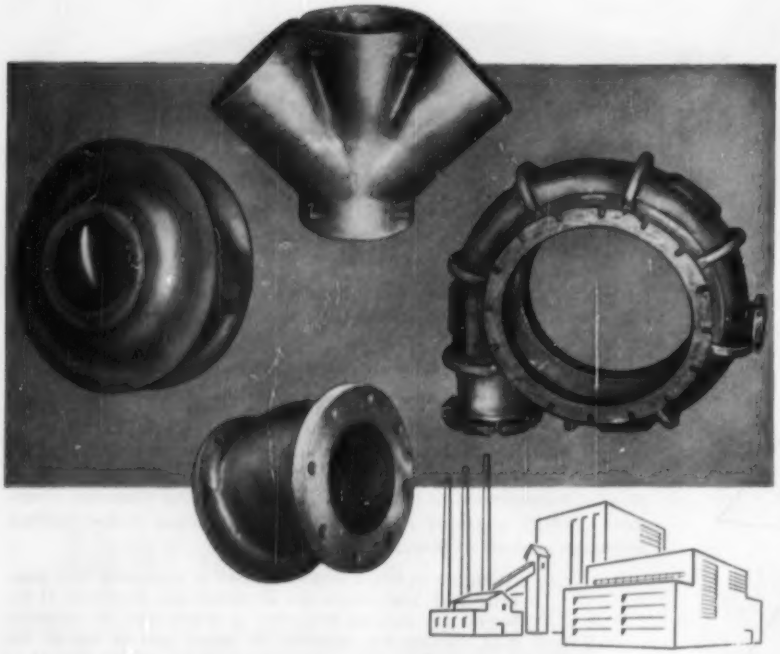
STANDARD RECORDERS Any standard industrial potentiometer recorder or pneumatic receiver can be used.

Arnold O. Beckman INC

Manufacturers of Industrial and Scientific Instruments

1020 MISSION STREET

SOUTH PASADENA, CALIFORNIA



Advertisers' Index

(Continued on page 73)